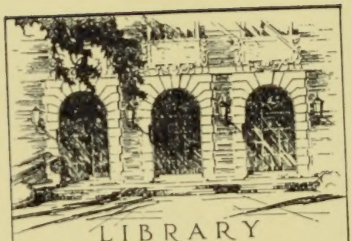

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May 21, 1910

Columbia University Bulletin of Information

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ANNOUNCEMENT

1910-1911

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Columbia University
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1. The Report of the President and the Treasurer to the Trustees.
2. The Catalogue of the University, issued in December, price 25 cents.
3. The Announcements of the several Colleges, Schools, and Divisions, issued in the spring, and relating to the work of the next year. These are made as accurate as possible, but the right is reserved to make changes in detail as circumstances require. The current number of any of these Announcements will be sent without charge upon application to the Secretary of the University.

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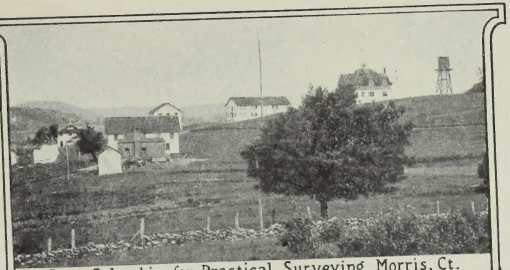

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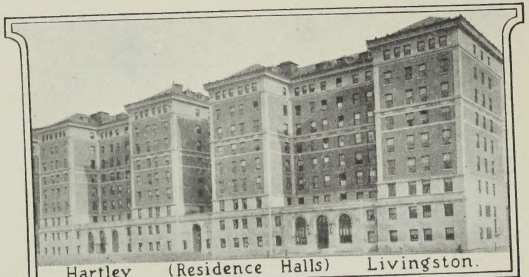

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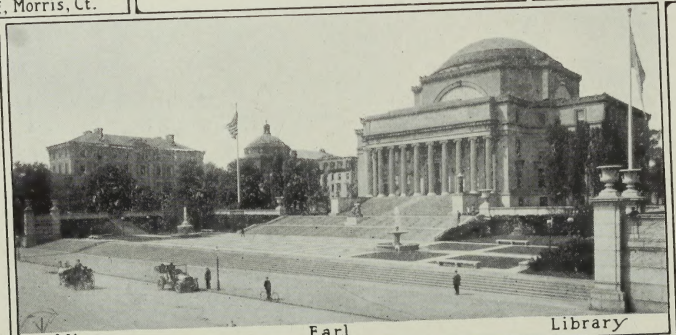

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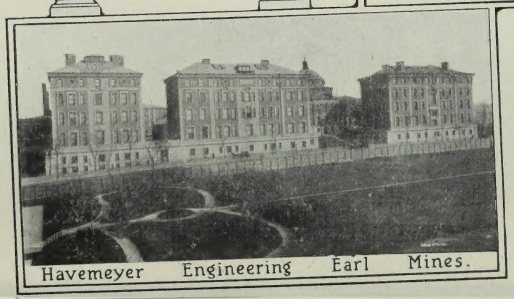

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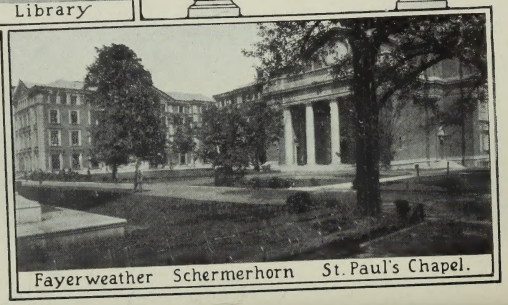

Fayerweather Schermerhorn St. Paul's Chapel.

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THE FACULTY OF APPLIED SCIENCE

The Faculty

NICHOLAS MURRAY BUTLER.....*President of the University*
A.B., Columbia, 1882; A.M., 1883; Ph.D., 1884; LL.D., Syracuse, 1898; Tulane, 1901; Johns Hopkins, Princeton, Yale, and University of Pennsylvania, 1902; Chicago, 1903; Manchester and St. Andrew's, 1905; Cambridge, 1907; Williams, 1908; Harvard and Dartmouth, 1909; Litt.D., Oxford, 1905.

FREDERICK ARTHUR GOETZE.....*Dean of the Faculty*
M.Sc., Columbia, 1905.

[1]CHARLES F. CHANDLER.....*Mitchill Professor of Chemistry*
A.M., Ph.D., Göttingen, 1856; M.D., University of New York, 1873; LL.D., Union, 1873; Sc.D., Oxford, 1900.

[3]HENRY S. MUNROE.....*Professor of Mining, and Delegate to University Council*
E.M., Columbia, 1869; Ph.D., 1876; Sc.D., 1904.

ALFRED J. MOSES.....*Professor of Mineralogy*
E.M., Columbia, 1882; Ph.D., 1890.

JAMES FURMAN KEMP.....*Professor of Geology*
A.B., Amherst, 1881; Sc.D., 1906; E.M., Columbia, 1884.

[2]ROBERT PEELE.....*Professor of Mining*
E.M., Columbia, 1883.

WILLIAM HALLOCK.....*Professor of Physics*
A.B., Columbia, 1879; Ph.D., Würzburg, 1881; Phar.D., National College of Pharmacy, 1892.

[1]FRANCIS B. CROCKER.....*Professor of Electrical Engineering*
E.M., Columbia, 1882; Ph.D., 1895.

MICHAEL IDVORSKY PUPIN.....*Professor of Electro-Mechanics*
A.B., Columbia, 1883; Sc.D., 1904; Ph.D., Berlin, 1889.

[3]WILLIAM H. BURR.....*Professor of Civil Engineering*
C.E., Rensselaer Polytechnic, 1872.

THOMAS SCOTT FISKE.....*Professor of Mathematics*
A.B., Columbia, 1885; A.M., 1886; Ph.D., 1888.

HAROLD JACOBY.....*Rutherfurd Professor of Astronomy*
A.B., Columbia, 1885; Ph.D., 1895.

[1]HENRY MARION HOWE.....*Professor of Metallurgy*
B.S., Harvard, 1869; A.M., 1872; LL.D., 1905; B.S., Mass. Institute of Technology, 1871; LL.D., Lehigh, 1905.

[1]CHARLES E. PELLEW.....*Assistant Professor of Chemistry*
E.M., Columbia, 1884.

EARL B. LOVELL.....*Professor of Civil Engineering*
C.E., Cornell, 1891.

[1]Absent on leave, 1910-11.
[2]Absent on leave first half-year.
[3]Absent on leave second half-year.

[1]George Francis Sever.....*Professor of Electrical Engineering*
M.Sc., Columbia, 1905.

[2]James Maclay.....*Professor of Mathematics*
C.E., Columbia, 1888; Ph.D., 1899.

Marston Taylor Bogert.....*Professor of Organic Chemistry and Delegate to the University Council*
A.B., Columbia, 1890; Ph.B., 1894; LL.D., Clark, 1909.

J. Livingston Rutgers Morgan.....*Professor of Physical Chemistry*
B.S., Rutgers, 1892; A.M. and Ph.D., Leipzig, 1895.

[2]Amadeus W. Grabau.....*Professor of Palæontology*
S.B., Massachusetts Institute of Technology, 1896; S.M., Harvard, 1898; S.D., 1900.

Ralph Edward Mayer.....*Associate Professor of Mechanical Drawing*
C.E., Columbia, 1879.

Cassius Jackson Keyser.....*Adrain Professor of Mathematics*
B.S., Missouri, 1892; A.M., Columbia, 1896; Ph.D., 1901.

Herschel C. Parker.....*Assistant Professor of Physics*
Ph.B., Columbia, 1890.

[3]George L. Meylan....*Assistant Professor of Physical Education and Medical Director of the Gymnasium*
M.D., New York University, 1896; B.S., Harvard, 1902; A.M., Columbia, 1904.

Lea McIlvaine Luquer.....*Assistant Professor of Mineralogy*
C.E., Columbia, 1887; Ph.D., 1894.

[1]Joseph C. Pfister.....*Assistant Professor of Mechanics*
A.B., Columbia, 1889; A.M., 1890.

Henry Clapp Sherman.....*Professor of Organic Analysis*
B.S., Maryland Agricultural College, 1893; A.M., Columbia, 1896; Ph.D., 1897.

Albert P. Wills.....*Professor of Mathematical Physics*
B.E.E., Tufts, 1894; Ph.D., Clark, 1897.

Samuel A. Tucker.....*Assistant Professor of Electro-Chemistry*
Ph.B., Columbia, 1895.

Adolph Black.....*Assistant Professor of Civil Engineering*
C.E., Columbia, 1894.

Charles Edward Lucke.....*Professor of Mechanical Engineering*
B.S., College of the City of New York, 1895; M.S., New York University, 1899; Ph.D., Columbia, 1902.

Walter Rautenstrauch.....*Professor of Mechanical Engineering*
B.S., Missouri, 1902; M.S., University of Maine, 1903.

William Campbell.....*Assistant Professor of Metallurgy*
B.Sc., Durham University, 1898; D.Sc., 1905; M.Sc., Royal School of Mines, 1903; Ph.D., Columbia, 1903; A.M., 1905.

Edward Lawrence Kurtz.....*Assistant Professor of Mining*
E.M., Columbia, 1893.

Carlton Clarence Curtis.....*Assistant Professor of Botany*
A.B., Syracuse, 1889; Ph.D., 1893; A.M., Columbia, 1892.

[1]Absent on leave, 1910-11.
[2]Absent on leave first half-year.
[3]Absent on leave second half-year.

ARTHUR L. WALKER.....*Professor of Metallurgy*
E.M., Columbia, 1883.

GEORGE BRAXTON PEGRAM.....*Assistant Professor of Physics*
A.B., Trinity College (N. C.), 1895; Ph.D., Columbia, 1903.

BERGEN DAVIS.....*Assistant Professor of Physics*
B.S., Rutgers, 1896; A.M., Columbia, 1900; Ph.D., 1901.

ADAM LEROY JONES.....*Chairman of Committee on Undergraduate Admissions and Secretary of the Faculty*
A.B., Williams, 1895; Ph.D., Columbia, 1898.

CHARLES H. BURNSIDE.....*Assistant Professor of Mechanics*
B.S., Columbia, 1898; A.M., 1899.

MORTON ARENDT.....*Assistant Professor of Electrical Engineering*
E.E., Columbia, 1898.

CHARLES P. BERKEY.....*Assistant Professor of Geology*
B.S., Minnesota, 1892; M.S., 1893; Ph.D., 1897.

JOHN H. MORECROFT.....*Assistant Professor of Electrical Engineering*
E.E., Syracuse, 1904; B.S., 1907.

WILLIAM B. FITE.....*Professor of Mathematics*
Ph.B., Cornell, 1892.

HERBERT E. HAWKES.....*Professor of Mathematics*
A.B., Yale, 1896; Ph.D., 1900.

GEORGE V. WENDELL.....*Professor of Physics*
B.S., Massachusetts Institute of Technology, 1892; Ph.D., Leipzig, 1898.

MILTON C. WHITAKER.....*Professor of Industrial Chemistry*
B.S., Colorado, 1897; M.S., 1899.

WALTER IRVINE SLICHTER.....*Professor of Electrical Engineering*
E.E., Columbia, 1896.

J. PAUL JONES WILLIAMS....*Assistant Professor of Civil Engineering*
B.S., Pennsylvania, 1898; M.S., 1899; C.E., 1908.

EDWIN R. A. SELIGMAN.....*McVikar Professor of Political Economy*
A.B., Columbia, 1879; A.M., 1883; Ph.D. and LL.B., 1884; LL.D., 1904.

GEORGE W. KIRCHWEY.....*Kent Professor of Law*
A.B., Yale, 1877; LL.D., Yale, University of Cincinnati, and New York University, 1908.

HENRY ROGERS SEAGER.....*Professor of Political Economy*
Ph.B., Michigan, 1890; Ph.D., Pennsylvania, 1894.

Associate

CHARLES BUXTON GOING.....*Associate in Mechanical Engineering*
Ph.B., Columbia, 1882.

Instructors

CHARLES C. TROWBRIDGE.....*Instructor in Physics*
B.S., Trinity (Ct.), 1892; M.S., 1903; Sc.D., 1908.

EVERETT J. HALL.....*Instructor in Assaying*

FLOYD J. METZGER.....*Instructor in Analytical Chemistry*
Ph.B., Buchtel, 1899; Ph.D., Columbia, 1902.

HARRY L. PARR.....*Instructor in Mechanical Engineering*
A.B., Columbia, 1902; Mech.E., 1904.

SAMUEL OSGOOD MILLER.....*Instructor in Drawing*
C.E., Columbia, 1895.

EDWARD F. KERN.....*Instructor in Metallurgy*
B.S., University of Tennessee, 1897; Ph.D., Columbia, 1901.

EDWARD K. JUDD.....*Instructor in Mining*
A.B., Williams, 1901; E.M., Columbia, 1904.

THOMAS H. HARRINGTON.....*Instructor in Drawing*
C.E., Columbia, 1889.

HAL T. BEANS.....*Instructor in Analytical Chemistry*
B.S., University of Nebraska, 1899; A.M., 1900; Ph.D., Columbia, 1904.

LEIGHTON B. MORSE.....*Instructor in Physics*
Ph.B., Iowa College, 1903; Ph.D., Columbia, 1908.

THOMAS McC. GUNN.....*Instructor in Mechanical Engineering*
A.B., Univ. of Washington, 1899; A.M., 1900.

HAROLD W. WEBB.....*Instructor in Physics*
A.B., Columbia, 1905; Ph.D., 1909.

CAVALIER HARGRAVE JOÜET.....*Instructor in Analytical Chemistry*
Ph.B., Columbia, 1882; Ph.D., 1894.

ARTHUR COLON NEISH.....*Instructor in Chemistry*
A.B., Queen's University, 1898; A.M., Columbia, 1900; Ph.D., 1904.

MAURICE A. LAMME.....*Instructor in Mineralogy*
B.S., Montana Agricultural College, 1903; A.M., Columbia, 1904; Ph.D., 1909.

ARTHUR RAY MAXSON.....*Instructor in Mathematics*
A.B., Rollins, 1900; A.M., Columbia, 1905.

LEWIS P. SICELOFF.....*Instructor in Mathematics*
A.B., Central College, 1900.

OTTO KRESS.....*Instructor in Chemistry*
B.S., Columbia, 1906; A.M., 1907; Ph.D., 1909.

CHESTER A. DARLING.....*Instructor in Botany*
A.B., Albion, 1904; A.M., 1906; Ph.D., Columbia, 1909.

CHARLES W. THOMAS.....*Instructor in Mechanical Engineering*
Mech.E., Stevens Institute, 1884.

JOHN M. NELSON.....*Instructor in Organic Chemistry*
B.S., Nebraska, 1901; Ph.D., Columbia, 1907.

HERMON W. FARWELL.....*Instructor in Physics*
A.B., Dartmouth, 1902; A.M., 1906.

HARRY W. REDDICK..... *Instructor in Mathematics*
A.B., Indiana, 1904; A.M., Illinois, 1906.

EDWARD D. THURSTON, JR.....*Instructor in Mechanical Engineering*
A.B., Columbia, 1905; Mech.E., 1907.

FREDERICK W. HEHRE.....*Instructor in Electrical Engineering*
E.E., Columbia, 1908.

WILLIAM C. MOORE.....*Instructor in Analytical Chemistry*
B.S., Peabody, 1903.

J. ENRIQUE ZANETTI.....*Instructor in Analytical Chemistry*
B.S., Harvard, 1906; A.M., 1907; Ph.D., 1909.

JAMES S. MACGREGOR.....*Instructor in Civil Engineering*
B.S., Mass. Inst. of Technology, 1902; M.S., 1904.

FRANCIS S. FOOTE, JR.....*Instructor in Civil Engineering*
E.M., Columbia, 1905.

NELS J. LENNES.....*Instructor in Mathematics*

Lecturers

WILLIAM S. DAY.....*Lecturer in Physics*
A.B., Columbia, 1884; Ph.D., Johns Hopkins, 1897.

ELIHU C. CHURCH.....*Lecturer in Civil Engineering*
C.E., Columbia, 1904.

FRANK F. ALMY.....*Lecturer in Physics*

Assistants

WILLARD L. SEVERINGHAUS.....*Assistant in Physics*
A.B., German Wallace College, 1904; A.M., 1905.

GAILLARD S. ROGERS.....*Assistant in Mineralogy*
A.B., Columbia, 1908; A.M., 1909.

LEON E. PENDER.....*Assistant in Physics*
A.B., Trinity (N. C.), 1907; A.M., 1908.

WILLIAM S. NELMS.....*Assistant in Physics*
A.B., Southwestern, 1903; A.M., 1904.

JOSEPH S. CORBETT.....*Assistant in Mathematics*
A.B., Columbia, 1909.

BERNARD O. DODGE.....*Assistant in Botany*
Ph.B., Wisconsin, 1909.

JAMES E. GRAY.....*Assistant in Mathematics*
A.B., Columbia, 1909.

JESSE E. HYDE.....*Assistant in Palæontology*
A.B., Ohio State University, 1906.

FRANK L. MASON.....*Assistant in Electrical Engineering*
E.E., Columbia, 1909.

WALTER ALFRED MITCHELL.....*Assistant in Physics*
B.A., Trinity (Ct.), 1901.

LEONARD D. NORSWORTHY.....*Assistant in Civil Engineering*
C.E., Columbia, 1909.

ANCEL ST. JOHN.....*Assistant in Physics*
Ph.B., Rochester, 1906.

RALPH H. SHERRY.....*Assistant in Metallurgy*
A.B., Stanford, 1904; A.M., 1905.

ANDREW W. JACKSON.....*Assistant in Physics*
A.B., Oregon, 1907; A.M., 1909.

JESSE E. BEANS.....*Assistant in Drawing*

HARRY L. FISHER.....*Assistant in Organic Chemistry*
A.B., Williams, 1909.

DAVID DALE CONDIT.....*Assistant in Geology*
A.B., Ohio State, 1909.

Non-Resident Lecturers for 1910-11

BENJAMIN LAWRENCE, M.Sc.....*Silver Mines at Cobalt, Ontario*
Consulting Mining Engineer.

ARTHUR S. DWIGHT, E.M.....*Rio Tinto Mines of Spain*
Consulting Engineer, New York City.

FRANKLIN GUITERMAN.....*Review of Smelting Progress in the West*
American Smelting and Refining Company.

CHARLES S. HERZIG, E.M.....*Concentration by Flotation at Broken Hill, Australia*
Consulting Mining Engineer, New York City.

D. M. RIORDEN.....*The West in the Early Days*
General Electric Company, New York City.

CHARLES R. TOWSON.....*Welfare Work at Mining Camps*
Secretary, Industrial Department, Young Men's Christian Association.

GUY W. CULGIN.....*Rapid Transit and the Mono Rail*
Assistant Engineer, Interborough Rapid Transit Company.

JAMES K. FINCH, C.E.....*Building Construction in New York City*
Contracting Engineer.

HENRY B. MACHEN, C.E..*High Pressure Fire Service in New York City*
Borough Engineer, Department of Water Supply, Gas and Electricity.

W. F. MORSE.....*Collection and Disposal of Municipal Waste*
Consulting Engineer.

H. W. WILSON.....*Structural Material. Investigation of the Technologic Branch of the U. S. Geological Survey*
Assistant Chief Technologist, Technologic Branch of the United States Geological Survey.

E. H. HEWLETT.....*Electrical Switchboards*
Switchboard Department, General Electric Company, New York City.

J. W. LIEB, Jr.....*Electric Lighting*
New York Edison Company.

ROBERT T. LOZIER.....*Commercial Phases of Engineering*
Consulting Engineer, New York City.

A. L. MCALLISTER.....*Alternating Current Commutator Motors*
Assistant Editor, Electrical World.

C. O. MAILLOUX, M.S., E.E.....*Specifications and Contracts*
Consulting Electrical Engineer, New York City.

HENRY PIKLER, E.E.*History, Theory and Manufacture of Transformers*
Transformer Engineer, Crocker-Wheeler Company, Ampere, N. J.

W. B. POTTER.....*Electric Railway Development*
Railway Department, General Electric Company, New York City.

C. SCHWARTZ.....*Power Stations*
Consulting Engineer.

PERCY THOMAS, E.E.....*High Tension Transmission*
Consulting Engineer, New York City.

F. K. VREELAND.....*Wireless Telephony*
Consulting Engineer.

HUGH AIKMAN.....*Forging Processes. Principles of Machine Manufacture*
J. H. Williams Company, Manufacturers of Drop Forgings.

WALTER BALLINGER....*Design and Construction of Modern Factory Buildings*
Consulting Engineer, Philadelphia, Pa.

CHARLES U. CARPENTER.....*Works Organization and Management*
President, Herring-Hall-Marvin Safe Company, New York City.

CHARLES DAY.....*Manufacturing Plant Design*
Day, Dodge & Day, Engineers, Philadelphia, Pa.

C. B. EDWARDS.....*The Design of Steam Turbines for Ship Propulsion*
Fore River Shipbuilding Company, Quincy, Mass.

HARRINGTON EMERSON.....*Works Organization and Management*
Consulting Engineer and Efficiency Expert, New York City.

H. F. T. ERBEN....*Characteristics of the Alternating Current Steam Turbo Generator*
Engineer, General Electric Company, Schenectady, N. Y.

H. L. GANTT.....*Works Organization and Management*
Consulting Engineer, New York City.

CHARLES B. GOING.....*Works Organization and Management*
Editor, Eng. Magazine, New York City.

CHARLES A. HAGUE.....*In charge of Pumping Machinery Course*
Consulting Engineer, Water Supply, Pumping Station Expert, New York City.

Mr. E. R. HARDY.....*Fire Protection*
Manager New York Fire Insurance Exchange, New York City.

G. K. HOOPER.....*Foundry Design*
Consulting Engineer, New York City.

RICHARD T. LINGLEY.....*Works Organization and Management*
Certified Public Accountant, New York City.

L. C. LOEWENSTEIN.....*The Design of Steam Turbines*
General Electric Company, Lynn, Mass.

WALTER MCFARLAND.....*Works Organization and Management*
Vice-President, Westinghouse Electric Company, Pittsburg, Pa.

FRED J. MILLER..*Standard Processes for the Manufacture of Machinery and Their Efficiency*
Vice-President, American Society of Mechanical Engineers, Consulting Engineer, Remington Typewriter Company.

PERCIVAL ROBERT MOSES.....*Heating and Ventilating of Factories*
Steam Power, Heating and Ventilating Engineer, New York City.

L. DEG. MOSS.....*In charge of course on Elevating and Conveying Machinery*
Consulting Engineer and Designer of Machinery for Mechanical Handling of Materials.

F. W. O'NEIL.....*In charge of course on Air Machinery*
New York Manager Nordberg Manufacturing Company, Compressed-Air Expert.

FRED. OPHULS....*In charge of the course on Refrigerating and Ice Making Machinery*
Estimating Engineer, De La Vergne Machine Company, New York City.

G. A. ORROK.....*Gas Engines Using Blast Furnace Gas*
Secretary, Gas Power Section, American Society of Mechanical Engineers, Mechanical Engineer, New York Edison Company.

H. DeB. Parsons.....*Fans and Blowers*
Consulting Mechanical Engineer.

R. J. S. Pigott.....*The Economy of Low Pressure Steam Turbines in Connection with High Pressure Reciprocating Engines*
Assistant Superintendent of Motive Power, Interborough Rapid Transit Company.

L. R. Pomeroy.....*Conditions Limiting the Electrification of Steam Trunk Line Railroads*
Engineer, Safety Car-Heating Company, and Consulting Engineer on Railroad Mechanical Problems.

E. J. Prindle.....*Works Organization and Management*
Patent Expert, New York City.

H. S. Reist.....*Characteristics of the Direct Current Steam Turbo Generator*
Engineer, General Electric Company, West Lynn, Mass.

Alfred Spangenberg.....*Time Saving in Assembling*
Foreman of Assembling Department, Niles-Bement-Pond Company, Plainfield, N. J.

H. F. Stimpson.....*The Structural Features of Manufacturing Plant Design*
Consulting Engineer, New York City.

G. W. Stone.....*Commercial Limitations to Steam Turbine Design*
Turbine Department, General Electric Company, Schenectady, N. Y.

Brainerd Dwyer.....*Carbon and Carbon Manufacture*
National Carbon Company.

Standing Committees of the Faculty

On Instruction. The Dean (Chairman), Professors Peele, Lovell and Lucke.

On Admissions. Professors Jones (Chairman), Mayer, Black and Rautenstrauch.

University Officers of Administration

Frank Diehl Fackenthal, A.B.....*Secretary of the University*
William A. Hervey, A.M.....*Registrar of the University*
Charles S. Danielson.....*Bursar*
Henry L. Norris, M.E.....*Superintendent of Buildings and Grounds*

Chaplain of the University

Rev. Raymond C. Knox, B.D.

Medical Director of the Gymnasium

George L. Meylan, M.D.

Secretary of Earl Hall

James Myers, A.B.

University Medical Visitor

D. Stuart Dodge Jessup, M.D.

INTRODUCTORY

Columbia University was founded in 1754 as King's College. In 1784, after the Revolutionary War, King's College became, by act of the Legislature of the State of New York, Columbia College. The institution whose name was thus changed has become Columbia University.

The first step for the foundation of a School of Applied Science was taken in 1864, when the Trustees approved the creation of a School of Mines, in which courses were later established in civil engineering, chemistry, and metallurgy. The growth of these courses, made it seem desirable to adopt some more comprehensive name than the historic title "School of Mines," so that in 1896 the Schools of Engineering and Chemistry were set off from the School of Mines, the three schools remaining, however, under the jurisdiction of a single faculty:

1. The School of Mines, with four-year courses leading to the degrees of Engineer of Mines and of Metallurgical Engineer.

2. The School of Engineering, with four-year courses in Civil Engineering, Electrical Engineering, and Mechanical Engineering, leading to the degrees of Civil Engineer, Electrical Engineer, and Mechanical Engineer respectively.

3. The School of Chemistry, with four-year courses, leading to the degrees of Chemist and Chemical Engineer.

The courses are intended to meet the requirements of the several professions indicated; and many of them permit a certain amount of specialization, particularly in the fourth year. The work in the School of Mines is so arranged that the student can emphasize the engineering, the metallurgical, or the geological side of his profession.

A course in Sanitary Engineering (leading to the degree of Civil Engineer) is provided for those who wish to prepare themselves for this important branch of civil engineering. The organization of a course in Forestry is under consideration, and it is hoped that in the near future a four-year professional course in Forestry, leading to the degree of Forest Engineer, will be established.

Candidates for a professional degree who have some special end in view are sometimes permitted to vary the regular course by substituting, for the courses ordinarily prescribed, courses for other degrees offered under the Faculty of Applied Science. Students holding an academic degree who become candidates for the degree of Master of Arts or Doctor of Philosophy may offer work in one or more of these branches of technology either as a major or a minor subject under the Faculty of Pure Science and will be given oppor-

tunity for special study and investigation (see page 23). Non-matriculated students, properly qualified by age, special training and experience and by ability, may sometimes pursue advanced studies of original research.

In the regular SUMMER SESSION held at the University in July and August of each year many courses of interest to engineering students are offered. The *Announcement of the Summer Session* will be sent upon application to the Secretary of the University. Attention is also called to the work in Extension Teaching, the Announcement of which may be obtained from the Secretary.

ADMISSION

Admission to the Schools of Mines, Engineering and Chemistry is obtained only by examination, with the exception that the certified credentials of approved degree-granting institutions may be accepted by the Committee on Admissions in lieu of examination in so far as they correspond specifically with the stated requirements.

Except for reasons of weight, candidates for admission to the first-year class must be at least eighteen years of age at the time of matriculation, and correspondingly older for admission to advanced standing. Each candidate must before admission present a certificate of good moral character from his last teacher or from some citizen of good standing. Students from other colleges or universities must bring certificates of honorable dismission. Students are admitted subject to the disciplinary powers of the University authorities.

All requests for information regarding admission should be addressed to the Secretary of the University.

Collegiate Preparation Recommended

The liberal training offered by a preliminary Collegiate Course is quite as important to engineers, metallurgists and chemists as to lawyers, physicians or clergymen, and is strongly recommended by the Faculty of Applied Science. This, however, does not and should not involve a residence of eight years in college and technical school before a candidate receives the professional degree.

A graduate of any good college who has selected his course with reference to future work in applied science is able to complete the requirements for a degree in the Schools of Mines, Engineering and Chemistry in less than four years after receiving the Bachelor's degree. The opportunities for close articulation between Columbia College and these Schools are, however, particularly good. Under the provisions of the new program it is possible for a well-prepared student to complete the requirements for both the collegiate and professional degrees in six years.

Requirements for Admission for Students without Collegiate Preparation

To the First Year Class

Every candidate must offer at the entrance examinations (see below) subjects amounting to fourteen and one-half "units." A unit represents a course of five periods a week for one year in the secondary school.

Total requirement.....14½ units

The candidate must offer:

	Counting in Units
Chemistry	1
Drawing	1
Elementary French *or* Elementary German	2
English	3
Mathematics	3½
Physics	1

and three units from the following:

Elementary German *or* Elementary French	*see above* 2	units
Elementary Spanish	2	"
Elementary Latin	2	"
Intermediate French	1	"
Intermediate German	1	"
Ancient History	1	"
Modern and Mediæval History	1	"
American History	1	"
English History	1	"
Botany	1	"
Physiography	1	"
Zoölogy	1	"
Shopwork	1	"

Candidates for degrees of Engineer of Mines, Metallurgical and Chemical Engineer or Chemist, are recommended to offer Elementary and Intermediate German.

It is suggested that candidates deficient in entrance subjects in June arrange to take courses in them in the Summer Session of Columbia University, the announcement of which will be sent upon application to the Secretary of the University. Certain of the entrance subjects may also be pursued under the Department of Extension Teaching.

The examination requirements for admission may be satisfied by any one of the three following means, or by any approved combination thereof:

Entrance Examinations

1. By the examinations of the College Entrance Examination Board. These examinations are held annually in June, in 1910, beginning on June 20th, at Columbia University and at about one hundred and fifty other educational centres in the United States and Europe. A complete list of the places and times of such examinations, together with the regulations governing them, may be obtained from the Secretary of the College Entrance Examination Board, Post Office Sub-Station 84, New York City.

2. By the examinations conducted by the Columbia University Committee on Undergraduate Admissions. These examinations are held in September and January of each year (beginning on September 19, 1910, and January 9, 1911), and only at the University.

3. By the examinations of the State Examination Board of the New York State Education Department. These examinations are held in January and June at more than six hundred high schools and other institutions throughout the State of New York, but, save in exceptional circumstances, are open only to students in those schools. Full information regarding the regulations governing them may be obtained by application to the New York State Education Department, Albany, New York.

A copy of the time-scheme of the examinations held by the College Entrance Examination Board in June, and by Columbia University in September and January, together with information as to the proper method of filing application-blanks for these examinations, the payment of fees, the division of examinations, and also detailed definitions of the requirements in each admission subject, is given in the Bulletin of Entrance Examinations and Admission for 1909, which may be had upon application to the Secretary of the University.

Restrictions Governing Examinations

A candidate may present himself at any of the series of examinations scheduled above, and the results may be credited toward the fulfilment of the requirements for admission, subject to the following restrictions:

1. A candidate in making application for examination must submit a statement from the principal of his school, or from his last instructor, indicating the extent and character of his preparation in each subject in which he applies for examination, and credit may be withheld when this requirement is not met.

2. The results of an examination may stand to the candidate's credit for twenty-nine months, but no longer.

3. A candidate may not present himself for examination more

than four times, except by special consent of the Committee on Admissions.

4. The results of the examinations conducted by the New York State Examination Board can be credited only in so far as the subject-matter of these examinations specifically covers the subjects, or lettered or numbered parts of a subject, which are accepted for admission to the Schools of Mines, Engineering and Chemistry. Candidates who have been granted the College Entrance Diploma issued by the New York State Education Department may be admitted to the Schools of Mines, Engineering and Chemistry free of conditions if the directions given on page 8 of the Columbia University Bulletin of Entrance Examinations and Admission have been observed. The diploma should be forwarded to the Secretary of the University together with the application for admission.

5. In order to be credited toward entrance, the reports of a candidate's examinations, together with the statement of the extent and character of his preparation in each subject offered, must be in the hands of the Committee on Admissions one week prior to the opening of the term in September or January.

6. The reports of all examinations must be rendered to the Committee on Admissions in percentages. The Committee interprets these percentages as Passed (P), or Failed (F). Credit toward admission is given only for such examinations as receive a grade of P.

To Advanced Standing

The uniform first year in the Schools of Mines, Engineering and Chemistry, and the efficient coördination of the subsequent years, make it possible for graduates of colleges and scientific schools to enter Columbia University with advanced standing and to complete the requirements for a professional degree without undue delay through conflicts and other causes. It is very desirable, however, that students in other colleges who are planning to take professional work after graduation should get into correspondence with the University as early as possible. If this is done they may receive advice with regard to the most advantageous collegiate subjects to elect, and also with regard to the summer courses of Columbia University. By taking certain summer work at the University in advance, a student sometimes may save six months or a year in entering upon his professional career. A separately printed leaflet on admission to advanced standing in these Schools will be sent on application to the Secretary of the University.

Candidates for admission to advanced standing should make application in writing to the Chairman of the Committee on Undergraduate Admissions in time to reach him on or before September 12, 1910.[1]

[1]When the candidate is at a considerable distance from the University, his application should, if possible, be made earlier than September in order that he

The application must be accompanied by properly certified official statements of his standing in the subjects which he offers.

The Committee will notify the candidate at the address given in his letter, between September 12 and 16, 1910, what courses, of those offered, are accepted as equivalent to courses at Columbia University. In general, the Committee gives credit for complete courses only.[1] In cases where the work previously done by the candidate has not been accepted by the Committee, the candidate should present himself at regular fall examinations during the two weeks immediately preceding the opening of the University (in 1910, September 19-26). For courses in which no regular fall examination is held, the candidate should report between 10 A.M. and 12 M. at the Dean's office. The schedule of fall examinations may be obtained from the Registrar.

Admission to Special Courses of Study

Graduates of these Schools, and other institutions of equal grade, may pursue any subjects taught in the schools for which they are qualified.

Persons of mature age who are not graduates, but who show special qualifications, are sometimes permitted to pursue special courses of study, but this permission is not given to others.

Except by vote of the Committee on Admissions no one will be admitted as a non-matriculated student who has been refused admission, or has failed in his work, as a candidate for a degree.

Persons who wish merely to pursue elementary subjects are not received as non-matriculated students.

Non-matriculated students will be held to the observance of the same regulations as to attendance, examination and proficiency as matriculated students.

Admission on Probation

Every first-year student admitted conditionally will be held under probation during the first half-year of residence. So far as possible, students on probation are given the opportunity in Columbia College or in the Department of Extension Teaching, to make good their deficiencies. Not later than the end of this period, the Dean, on the basis of reports from the head of each department in which the student is registered, will decide whether he shall be admitted to full standing, have his period of probation extended, or be dropped from the roll. The mark of 7 or higher, obtained in any subject at the end of the first half-year of residence, will be regarded as removing an entrance con-

may receive the reply in time to present himself at the University on September 19, 1910.

[1]In cases where credit for part of a course might be given, the candidate should present his case to the Chairman of the Committee on Admissions, at the times given above, bringing drawings, note-books, or other evidence showing the scope and character of his work.

dition in that subject, unless the condition was incurred in a part of the subject not directly involved in the work of the course. Any condition not so removed must be satisfied by formal examination.

ADVICE TO STUDENTS

Each student is on entrance assigned to an officer of instruction, who acts as his academic adviser. The adviser is kept informed as to the attendance and standing of all such students in their academic work and as to the extent and character of their participation in extra-curricular activities, and he advises students on all these and other matters that concern them as students.

Reports of standing are sent to the student, his parent or guardian, his adviser and to the Dean every five weeks for students in the first and second classes and at the end of each term for students in the third and fourth classes.

A student who has not been assigned to an adviser may apply to the Dean for such assignment.

REGISTRATION

Before attending any University exercises each student must register, *i. e.*, must present himself in person to furnish the information necessary for the University records and to file a statement of the courses he is authorized to pursue (for the matriculation or registration fee, payable but once, see below).

The office of the Registrar, 201 East Hall, will be open for registration from Wednesday, September 21, to Tuesday, September 27, 1910. New students may register also on September 28. Credit for attendance will date from September 28.

Students prevented, through no fault of their own, from completing their registration in due time, should file a provisional registration-record.

Registration at a later date is permitted only to candidates who obtain the written consent of the Dean, satisfactory cause for the delay having been shown. (For the fee for late registration see below.)

Students holding scholarships are required to report themselves as in residence to the Registrar at the opening of each half-year.

Honorable Dismissal

In case of withdrawal during the academic year, students are requested to file a notice thereof with the Registrar, on a blank form provided for the purpose. An honorable dismissal is granted by the Dean to any student in good standing over twenty-one who may desire to withdraw, and, with the written assent of his parent or guardian, to a student under that age. Applications for leave of absence should be addressed to the Dean.

FEES

The President is under instructions to withdraw the privileges of any student delinquent in payment after the second Wednesday of each half-

year. All regulations as to fees are subject to change by the Trustees at their discretion.

For Matriculation or Registration: Required of all students on entrance, payable but once..... $5

For late Registration (see above)..... 5

For Tuition in the Schools of Mines, Engineering and Chemistry, payable at the beginning of each half-year: For matriculated students for each half-year..... $125

For non-matriculated students, $7.50 per half-year for each hour of attendance upon lectures and recitations per week; with additional charges for laboratory work up to $25 per half-year when the number of hours weekly of such work does not exceed nine, and of $40 per half-year when the number of hours weekly exceeds nine; the whole not to exceed $125 per half-year.

For the use of the Gymnasium: Required of all student who do not hold an academic degree; optional for students holding such a degree..... 7

For examinations, payable in each case before the examination is held:

For entrance (see p. 13 *et seq.*)..... 5

For a deficiency examination or series of deficiency examinations held in the week preceding the opening of the first half-year, for each course $5, with a maximum of..... 25

For a deficiency examination at any other time than in the period designated above, whether taken at the conclusion of a course repeated by the student or without such repetition, for each course..... 5

For special examinations at unusual times:

For admission, for the series..... 5

For removal of deficiencies in course, for each course..... 5

For any professional degree, payable prior to filing of application[1] 25

Laboratory Fees

Students not candidates for a degree, as well as all candidates for the higher degrees, are charged, in addition to the prescribed tuition fee, a fee for certain laboratory courses and for the use of laboratories, up to a maximum fee of $125 per half-year, including tuition. The schedule of such fees may be obtained from the Registrar.

Summer Courses in Surveying

Laboratory fees, payable on or before the last Saturday in May, are required as follows: Civil Engineering course No. 15, $25, or $7 per survey; No. 25 and No. 27, $15, or $5 per survey; No. 26, $5; No. 28 and No. 71, $10.

Non-candidates, candidates for admission to, and students having entered with advanced standing, who may be required to attend these

[1]Refunded to unsuccessful candidates upon application to the Registrar not later than June 20 next ensuing.

courses, and students required to repeat them through delinquency, are charged in addition tuition fees as follows: No. 15, $35; No. 25, No. 27, No. 28, and No. 71, $25; No. 26, $10. Students entering with credit for part of course 15 shall pay a tuition fee of $10 for each survey. A tuition fee of $6 is required for each survey of courses 25 or 27 taken under similar condition. In the case of a student registered in Columbia College who has paid an additional fee under the operation of this rule, an equitable credit will be made should he later complete the requirements for a professional degree. In the case of a student admitted to advanced standing the additional fee may be refunded in whole or in part, according to regulations which may be learned from the Registrar.

Deposits for Apparatus, Supplies and for Keys to Desks and Lockers

A deposit for the use of lockers, keys, apparatus, material, and the like, ranging from $1 to $40, is required of students in Mines, Engineering and Chemistry. At the end of the academic year each student will be credited with those articles which he returns in good order, and the value of those he has injured or broken will be deducted from his deposit. Details may be obtained from the Bursar.

Residence Halls and University Commons

(See page 142.)

Employment Committee

(See page 141.)

Comparative Statement of Students' Probable Expenses for the Academic Year

	Low	Average	Liberal
Matriculation	$ 5	$ 5	$ 5
Gymnasium	7	7	7
Tuition	250	250	250
Books	30	45	60 up
Drafting material	2	10	15 "
Chemical apparatus	25	30	40 "
Room (37 weeks)	75	129	160 "
Board (37 weeks)	150	180	205 "
Clothes and laundry	25	40	75 "
College incidentals	2	5	25 "
Other expenses	10	25	75 "
Summer Courses in Surveying			
Tuition	25	25	25
Travelling	5	5	5 up
Board (5 weeks)	35	35	35 "
	$646	$791	$982

The expense for summer courses in surveying applies to all curriculums during the first summer only; for Mining and Metallurgical Engineering students during two summers; for Civil and Sanitary Engineering three summers.

RULES GOVERNING STUDENTS

1. A student cannot be a candidate for more than one professional degree at the same time.

2. A candidate for a degree must comply with all requirements in force at the time said degree is conferred.

3. A student will be permitted to substitute one subject for another provided he obtains the consent of the Dean, the heads of departments concerned and the head of the department giving the technical instruction leading to the degree.

4. A student absent from more than one-tenth of the required exercises will be debarred from examination in that subject. No student shall be exempt from this regulation except by action of the Committee on Instruction.

5. After examinations have been held, officers shall send to the Registrar a list of all students who have attended their courses, indicating proficiency by numbers on a scale of 10, a mark below 6 signifying a failure to pass. Reports of standing will be sent to First and Second year students every five weeks and to the Third and Fourth year students at the end of each term. Copies of all reports are at the same time sent to the Dean, to the Faculty Adviser and, in the case of First and Second year students, the parent or guardian. They will be sent to the parent or guardian of Third and Fourth year students only on request.

6. Regular examinations may be held at the end of the 1st and 2d term or both, or at the completion of any course.

7. Special examinations for students debarred or deficient at regular examination shall be held during the two weeks in September preceding the opening of the next following academic year; and for members of the fourth class in subjects belonging to that year only, during the first week in May.

8. Failure to pass a Summer Session course, credit for which would be accepted as equivalent to a regular undergraduate course in the Schools of Mines, Engineering and Chemistry, shall be counted, in case a student registers for said course, as one of the three failures referred to in Rule 10.

9. The fee for special examinations is $5 for each course, which must be paid when the application is made. For special examinations in the September series the maximum fee is $25.

10. A student failing to pass in any subject at the regular examinations must present himself for special examination as provided under Rule 7.

Failing to pass the second examination, he must repeat the subject with the next class. Failing a third time to pass a satisfactory examination he shall be dropped from the roll of the School.

11. Absence from any regular or special examination provided for in Rules 7 and 8 shall count as a failure unless excused by the Dean for reasons of weight.

12. No student having an entrance deficiency shall be permitted to register for any subject of the second, third or fourth year without the written consent of the Dean, and no student shall be permitted to register for any subject the prerequisites for which have not been satisfied by him unless the Dean, for reasons of weight, grants him special permission.

13. Any student who shall have passed a satisfactory examination in Columbia College in any subject forming a part of one of the professional courses in the Schools of Mines, Engineering and Chemistry will not be required to pursue that subject a second time.

14. During vacations following the close of each year, memoirs on assigned subjects must be prepared by the students in the courses of Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, and Chemistry. The time specified for the completion and handing in of memoirs is the first Monday in November.

A student failing to hand in his memoir, drawings or other summer work shall be considered to have failed; to have his work received later, he will be obliged to pay a fee of $5, as for a special examination.

15. By permission of the Dean, and concurrence of the heads of departments concerned, a student may attend subjects not required for his degree, provided such attendance does not interfere with his regular work. He must fulfill all the requirements exacted from regular students in such course.

Application for each special examination, except as provided below, must be filed at the office of the Registrar at least one week before the examination is to be taken, and in September and May at least one week before the first day of the respective examination period (in 1910-11 not later than Monday, September 19, and Monday, April 24, respectively). For later application an additional fee of $5 for any examination or series of examinations will be charged. Applications must be made on blanks (one for each course) to be obtained from the Registrar.

During the academic year students will be held responsible for the receipt of reports and other official communications sent to them at the coat room in Havemeyer Hall. During the summer vacation they will be held responsible for the receipt of such communications sent

to their home address as given on their registration blank for the preceding academic year.

SCHOLARSHIPS

Forty-one scholarships of $250 each, payable in semi-annual instalments during the maintenance of a satisfactory grade, are available to students in Mining, Engineering and Chemistry who are in good academic standing, and in need of pecuniary aid. Scholars are not exempt from the payment of fees.

Applications for appointment or reappointment should be made on blanks furnished by the Secretary of the University, and filed with him on or before May 1.

Awards will be made not later than July 1 by the Committee on Scholarships. Scholarships not allotted at this time, or becoming vacant, may be filled by the Committee at its discretion.

In detail these Scholarships are as follows:

Open to students who have been in the University at least one year—7 J. Pierpont Morgan, 7 Cornelius Vanderbilt, 10 D. Willis James, 1 Morris K. Jesup, 1 Samuel D. Babcock, 1 Oswald Ottendorfer.

Open to students of any class—8 Faculty, 5 Special, 1 Benjamin B. Lawrence, 1 Richard Butler (open to students born in Ohio; for special regulations see University catalogue).

In addition 40 Pulitzer Scholarships, carrying free tuition and a stipend of $250, are open to competition by students in the New York City High Schools. For details see the University catalogue.

Marcus Daly Scholarship in Mining Engineering

The Marcus Daly Scholarship of the annual value of $1,000, maintained by Mrs. James W. Gerard in memory of her father, is open to that worker or descendant of a worker in the Montana mines who passes the best competitive entrance examinations. The winner holds the same throughout his course in mining engineering conditionally upon his maintaining a grade of at least 6.75 in all subjects. The next scheduled competition will be in 1911.

MEDALS AND PRIZES

Prize of the New Jersey Alumni Association

A prize of $50 is awarded annually by the New Jersey Alumni Association to the New Jersey student who passes the best entrance examinations to the Schools, with the proviso that before the award the student shall complete satisfactorily one half-year of academic work.

Barnard Medal A gold medal valued at $200, endowed by President Barnard, is awarded quinquennially (next award, 1910) on the recommendation of the National Academy of Science to the person who within the five years next preceding shall have made such discovery in physical or astronomical science, or such novel application of science to purposes beneficial to the human race as shall be esteemed most worthy of such honor. For details and for a list of previous awards see the Annual Catalogue of the University.

Illig Medals A bequest of $2,000 by William C. Illig, E.M., '82, provides for the annual award of medals to the student or students in the graduating class of these Schools who shall, in the judgment of the Faculty, have merited the same by commendable proficiency in their regular studies.

Darling Prize A prize in Mechanical Engineering, the income of $1,000, bequeathed by Edward A. Darling, formerly Superintendent of Buildings and Grounds, is awarded annually to the most faithful and deserving student of the graduating class in mechanical engineering, the recipient to be chosen by members of the graduating class in that Course from among three names to be chosen by the Faculty.

OPPORTUNITIES FOR ADVANCED INSTRUCTION AND RESEARCH

Special attention is called to the opportunities offered through the Faculty of Pure Science to men who have received the Bachelor's degree or its equivalent from any recognized college or scientific school for advanced instruction and research in Mining Engineering, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering and Chemistry, leading to the degrees of A.M. and Ph.D. Any of the subjects mentioned above may be offered as a major or minor for either of these degrees. An outline of the courses in these subjects which may be offered toward the higher degrees by candidates who have completed the necessary prerequisites will be found in this announcement (see pp. 85, 92, 107, 112 and 118 *et seq.*), and the general regulations as to graduate work are printed in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science,* which may be had upon application to the Secretary of the University. Ordinarily, the degree of Master of Arts may be obtained after one year's work in residence and the degree of Doctor of Philosophy after three years, the minimum requirement for the latter degree, however, being two years. See also p. 144.

UNIFORM CURRICULUM FOR THE FIRST YEAR

The curriculum for the first year of the four year courses leading to the degrees of Engineer of Mines, Metallurgical, Civil, Electrical, Mechanical and Chemical Engineer and Chemist is the same in every respect and the student entering the first year class need not declare which course he will follow until the beginning of the second year, when he will have the advantage of the experience gained during the first year's work, where uncertainty exists respecting inclination or natural bent.

As will be seen in the tabular statement given below this first year is mainly devoted to a thorough grounding in Mathematics, Physics and Chemistry, the three fundamental subjects which form the indispensable basis for all broad and successful engineering work, not only in the remaining years of the course, but throughout the entire professional career. Specialization begins to some extent in the second year and becomes more marked in the third and fourth years.

The class is arranged in two divisions, Division B completing Engineering Drafting and Descriptive Geometry in the first term while Division A is completing Qualitative Analysis, the two divisions reversing the operation in the second term. This plan secures greater concentration of work; it facilitates the transfer of students to advanced standing from other institutions; and it enables well prepared students entering in February and taking advantage of the University Summer Session to catch up with their class by the following autumn.

To secure the most effective individual instruction the class is also divided for quizzes and recitations into six, eight, and in some cases twelve sections.

First Half Year			Hours per week	
See Page			Class	Lab'y
71	Chemistry 3	General Inorganic Chemistry	3	
86	Drafting 1	Engineering Drafting	1	14
86	Drafting 3	Descriptive Geometry	3	
95	Mathematics 1	Algebra	2	
95	Mathematics 3	Analytical Geometry	3	
119	Mechanics, 1	Elementary Mechanics,	2	
119	Phys. Educ. A	Gymnasium		2
120	Physics 3	Elementary Mechanics, Properties of Matter and Heat	5	
		Total..	19	16
Second Half Year				
78	Civil Eng. 2	Theory of Surveying	2	
71	Chemistry 4	General Inorganic Chemistry	3	
73	Chemistry 62	Qualitative Analysis	4	13
95	Mathematics 2	Differental Calculus	2	
95	Mathematics 4	Analytical Geometry	3	
119	Phys. Educ. A	Gymnasium		2
120	Physics 4	Light, Sound, Electricity & Magnetism	3	
		Total..	17	15

SUMMER WORK: Civil Eng. 15s. Five weeks of surveying practice.

MINING ENGINEERING

General Statement

The instruction in the School of Mines during the first and second years includes fundamental training in mathematics, physics, mechanics, chemistry, mineralogy, and geology as outlined in the program of studies on page 24. Laboratory instruction in chemistry, assaying, drafting, mineralogy and geology extends through three years.

In the engineering, mining, and metallurgical laboratories the student is given opportunity for experimental study of these subjects, supplementing and illustrating the instruction given in the class room. These laboratories are also equipped to train the student in the making of scientific tests of engineering materials, and working tests of machines and processes of ore treatment, thus preparing him, as far as it is possible in the school, for work that he will be called upon to do as an engineer.

Practical instruction in summer classes in the field is made an important feature of the curriculum. Details of the summer courses in mining, metallurgy, field geology and surveying will be found on pages 29, 30 and 31.

While much time is given to practical training in the laboratories, in the field, and at the mines and metallurgical establishments, care is taken to subordinate this instruction to a high standard of accomplishment in the regular classroom work.

The courses are severe, and should be undertaken only by those who are well prepared physically, mentally, and by previous training to devote themselves earnestly to the work required of them.

Advanced Students and Graduates can choose their subjects and plan of work much more freely than undergraduates.

Suggestions as to graduate work will be found on pages 118-119.

Situation—Many coal, iron, and other mines, together with quarries and metallurgical works, are easily accessible from New York in from one to four hours by rail. Among these are magnetic iron mines in New York, New Jersey, and Pennsylvania; stone quarries in the same States, and in Connecticut; anthracite and bituminous coal mines, and natural gas and oil wells in Pennsylvania, and zinc mines in New Jersey. New York and the adjacent States produce each year about half the pig-iron and coal, and over fifty per cent. of the total value of the mineral product of the whole country. There are within easy reach of New York City iron blast furnaces and some of the most skilfully designed and managed steel works, rolling mills, steel and iron foundries, copper smelting and refining works, lead refining works, zinc works, and electrolytic establishments in the world. New York City, moreover, is the headquarters of many corporations operating

mines and metallurgical works in this and other countries. Within a radius of one hundred miles may be studied many phases of the best practice in mining and metallurgy in the country. By going a little farther one may reach the bituminous coal fields and the natural gas, oil and salt regions in one direction, and the pyrite deposits, and granite and marble quarries of New York and New England in the other; while the excursions of the summer class in mining extend as far as the copper, iron, zinc, lead, silver, and gold regions of Michigan, Missouri, Montana, Colorado, California, Arizona and Utah (see page 29).

Building—The six-story School of Mines building, given by Mr. Adolph Lewisohn, is 145 feet long by 57 feet in width. The basement and sub-basement contain the ore-dressing laboratories. On the main floor are the mining and metallurgical museums and lecture rooms. On the second floor are the offices of the department of mining, the mining and metallurgical department libraries, a drafting-room for the design work of the fourth year, and one of the metallurgical laboratories. On the third floor are the offices of the department of metallurgy, the furnace rooms, the chemical laboratory, metallographic laboratory, and the research laboratories of the same department.

Equipment

Lecture Illustrations—The lectures on mining are illustrated by sets of books aggregating over 300 volumes, and containing 85,000 selected blue prints, each student having the use of books of prints for home study and for reference during the lectures. These illustrations are supplemented by lantern slides or wall diagrams.

Mining Library—The University library contains complete sets of the transactions of all mining, metallurgical, and engineering societies, and of the more important periodical publications on these subjects. There is also a large collection of books on mining, and all new publications of value are added as they appear. In addition, a small departmental library has been created, which is accessible to students at all times.

Mining Museum—The subject of mining is illustrated by collections, as follows: Maps of coal and metal mines of this and other countries. Working drawings, diagrams, and photographs of mine plant, and of mining and dressing machinery. Models of mines and parts of mines, and of mine plant. Mining tools: picks, shovels, hammers, drills, blasting apparatus, lamps, safety-lamps, anemometers and machine drills. Ores and dressing products from typical works in this and other countries. Surveying instruments: geological compasses and clinometers, attraction compasses, dipping needles, hanging compasses and arcs, transits, lamp signals, rods, and apparatus for plumbing and measuring shafts.

Among the more notable exhibits is a large relief model of one of the mines of the Cleveland-Cliffs Iron Mining Co. of Michigan, a similar model of a typical gold mine in Colorado, and a set of three glass models and two relief models of the Copper Queen Mine in Arizona, a model of the mine workings in the Mahonoy and Shenandoah anthracite coal basins Pennsylvania, a glass model of the mine workings on the Calumet Conglomerate of Houghton County, Michigan, a model of a standard oil-well drilling rig, and a model of the St. Joseph Lead Co.'s dressing works at Bonne Terre, Missouri.

A collection of working drawings of mine plant, and a large collection of underground photographs, taken by magnesium light, are worthy of special notice.

Mining Laboratories—These laboratories, occupying seven rooms, serve to supplement the study of ore concentration and milling made by the student as a part of his summer work, and afford him facilities for such study that cannot well be given at the works. They include the following:

The Laboratory for Mechanical Assays contains appliances for quantitative work in hand picking, jigging and vanning small samples of ore, and for panning gold-bearing gravel. For small scale working tests there are a number of specially designed laboratory classifiers, laboratory jigs, and laboratory slime tables.

The Crushing and Sampling Laboratory contains machinery for crushing and sampling large and small lots of ore, including gyratory and jaw crushers, rolls, a sample grinder, ball and pebble mills for fine crushing, gyratory screens, automatic samplers, and laboratory crushers, together with sieves, riffle samplers, etc.

The Laboratory for Working Tests contains a small vanning jig, an air jig, a buddle, a keeve, magnetic and electrostatic separators, and other similar apparatus for working a ton or more of ore at a time.

The Laboratory of Dressing Machinery contains full-sized machines of standard types, each arranged so that the products, heads, middlings and tailings are returned at once to the same machine for re-treatment. With a small quantity of ore each machine can thus be operated as long as may be necessary, and the student is afforded an opportunity to become familiar with the adjustments of the machine and the tests of proper and successful working. The apparatus now installed includes three Harz jigs of two, three and five compartments, a Richards' pulsator jig and two pulsator classifiers, two round tables, concave and convex, a Johnston vanner, a Wilfley table, and a Stein-Bilharz belt table. On the floor below are full-sized classifiers, dewatering cones, automatic feeders, and centrifugal pumps for supplying these machines with water and ore for continuous work.

Mining Laboratory Instruction

The work required is designed (1) to illustrate the physical laws and practical conditions affecting the mechanical concentration, separation, and purification of minerals; (2) to instruct the students in the details of quantitative working tests on both small and large scale; (3) to train them in the adjustment and operation of the standard types of concentrating machines, and in testing the efficiency of such machinery in actual operation, and (4) to give opportunity for original research.

The work includes the reduction of a ton or more of ore to laboratory samples, and tests on portions of this ore by handpicking, hand jigging, and mechanical treatment on laboratory jigs, classifiers, and slime tables, to determine the proper method of mill treatment. These tests are controlled by crushing and vanning samples of the products, and reports of the results obtained are made in a systematic manner.

The large concentrators are arranged to be run continuously, for as many hours as may be necessary, using the same ore and the same water again and again. This is accomplished by running the products of the several machines through dewatering cones, from which the mixed material is transferred to the hoppers of automatic feeders. Variable speed pulleys permit any desired adjustment of the driving mechanisms. The water supply is drawn from a constant level tank fed by a centrifugal pump, and is regulated by dial cocks. Other adjustments are equally under control and can be varied at will.

With each of these machines the student makes a series of experiments designed to bring out the physical laws governing successful working, to afford instruction in the practical details of operating the machines, and to give opportunity for engineering tests of capacity and efficiency under different conditions of treatment. These include the adjustment and regulation of the ore supply, of the feed and wash water, of speed, stroke, and other working conditions to the treatment of different ores and different grades of sand and pulp. In this work the student is taught to recognize the symptoms of irregular working, to diagnose the trouble with the aid of laboratory tests, and to apply the proper remedy. Incidentally he makes tests of capacity and efficiency, taking frequent samples of the ore feed, and of the different products for quantitative examination, and weighs and measures the ore and water supply and products obtained.

Experiments of this kind for purposes of instruction cannot well be made at concentration works in the field. Here the machines must work regularly and without interruption, and any interference with the ore feed, water supply, or other adjustments may occasion loss of valuable mineral.

Research Work—The laboratories have facilities for original investigation in the physical laws controlling the mechanical treatment of minerals.

Original researches have recently been undertaken by graduate students in:

Investigation of magnetic fields with reference to ore-concentration; the effect of variations in the speed of crushing machinery on the production of undersized material; the amalgamation of gold ores; an investigation of the laws of jigging.

Mining Thesis

The subjects for the graduation theses are assigned during the third year, and are made a part of the regular course of instruction. The subject given in each case is the problem of the opening and development of a mine, supposed to be located in some well-known mining district, and for which certain definite conditions as to size and character of ore body, amount of water to be pumped, and quantity of ore to be mined, are assumed. During the summer field work in mining the student incidentally obtains data for his thesis work. This information is supplemented by study of books and technical literature. During the fourth year he decides upon the proper methods for opening, developing, and working the property; and makes estimates of the plant, machinery and capital required, the cost of working, and the probable profits. He also works out in detail certain portions of the proposed mine plant, and prepares a set of working drawings, bills of materials and specifications therefor. This work, done under the supervision of competent instructors, constitutes both a review and a series of practical applications of the preparatory studies and enables the students to discover and remedy their deficiencies, giving them confidence in their ability to work out similar problems later.

Summer Courses

Summer Courses in Surveying—These courses are conducted during thirteen weeks of the summer vacations at a large farm owned by the University near Litchfield, Conn. About five weeks' attendance is required of each class between the first and second years, and eight weeks between the second and third years. A fuller statement with regard to this work will be found on page 44.

Summer Course in Practical Mining—Eight weeks are spent, usually under the supervision of the Department, in detailed study of the plant and methods of working at some mine or mines, in mine surveying, and in excursions to other mines and mining regions. The course includes shaft-sinking, drifting, stoping, timbering, underground haulage, hoisting, mine drainage, ventilation, surface plant, mine build-

ings, repair shops, houses, etc., water supply, organization, administration, and underground surveying. The students are divided into small squads, and assigned each day to a foreman, or working gang of miners, for the study of some definite subject. Each squad is visited frequently by the instructor, who examines their work and indicates subjects demanding special study and observation. Manual labor and the acquirement of manual dexterity are subordinated to the development of his powers of observation, and to the careful study of the work going on about him, and the recording of his observations and study in notes and sketches taken on the spot. The students' note-books are examined and criticised each evening. By thus systematizing the work of the student, time is economized, and the work done more thoroughly. Arrangements are also made at other mines, by which the students, singly or in small groups, may substitute for the class-work described above independent study, according to a definite plan and under the general direction of the department.

These summer courses have been in operation since 1877, and have proved themselves an indispensable adjunct to the regular curriculum. They bear the same relation to the study of mining as laboratory work to the study of chemistry or physics, or clinical instruction and hospital practice to the study of medicine.

In 1907, the class was distributed in small squads at gold, silver, copper and iron mines in Michigan, Minnesota, Montana, Colorado, Arizona and British Columbia. The time occupied was from 7 to 10 weeks. Several members of the class obtained positions at mines for the entire summer.

In 1908, a division of the class, in charge of an instructor, studied at the lead mines of the Federal Lead Co., Flat River, Mo., and the zinc mines of the Joplin district, Mo. The larger part of the class was sent out in separate squads to copper, iron, gold and silver mines in the West, at which arrangements were previously made and the necessary privileges secured. Among these mines were the Wolverine, Michigan; Golden Reward, Mogul and Homestake, South Dakota; Silver Bow and others of Butte, Montana; the properties of the Tennessee Copper Co., and a number of mines in Bisbee, Tombstone, Cananea, Cripple Creek and Leadville. Several members of the class obtained underground work in the Center Star and War Eagle mines, British Columbia, in Butte and elsewhere. The class numbered 40 men.

In 1909 the entire class of 39 students was again distributed in small squads at gold, silver, copper, zinc, lead, coal and iron mines, in Colorado, Utah, Arizona, Idaho, Montana, Michigan, Missouri, Tennessee and Pennsylvania. The time occupied was from 7 to 10 weeks. This work was preceded by one week's underground surveying, in charge of instructors, at the Orchard iron mine, near Dover, N. J.

In 1905 and 1906 the non-ferrous summer class in metallurgy visited

copper, lead, gold, silver and zinc works in the vicinity of New York City. The work in iron and steel was performed at several iron and steel works in the vicinity of Pittsburg in 1905. In 1907 students in metallurgy visited more than twenty iron and steel plants near Pittsburg. In 1908 and 1909 this work was done chiefly in the several districts visited by the squads of mining students.

In addition to these courses the students visit several iron and steel works in the neighborhood of New York during the Easter vacation. This visit is optional for all students who are taking, or have taken, Metallurgy 5A or 4.

Summer Courses in Geology—One week is devoted to practical field geology. The class is instructed in methods of field observation, locating outcrops, measuring dip and strike, keeping notes, etc., afterward constructing maps and geological sections from the observations noted; all under the supervision of the Professor of Geology.

Other Departments

Information as to instruction and the equipment available for students of Mining and Metallurgy in other departments of the University is to be found in this pamphlet as follows:

Chemistry and Assaying, 71; Civil Engineering and Surveying, 78; Electrical Engineering, 87; Geology, 93; Mathematics, 95; Mechanical Engineering, 96; Mineralogy, 113; Physics and Mechanics, 119; Metallurgy, 108.

ENGINEER OF MINES

The four-year course leading to the degree of Engineer of Mines is intended primarily to train men to undertake the development of mineral properties, the design and construction of mine plants, and to manage mines. The course includes training in metallurgy. It is necessarily a broad one, comprising a wide range of studies in pure and applied science, and for this reason is frequently taken by students desiring a general scientific training.

The subjects most emphasized in this course are mining, metallurgy, geology, and engineering. Metallurgy requires knowledge of inorganic and applied chemistry, qualitative and quantitative analysis, and assaying. Geology must carry with it preliminary training in crystallography, mineralogy, and petrography.

Engineering in all its branches needs a fundamental knowledge of mathematics, physics, mechanics, and thermodynamics. The proper design and construction of mining plants involves the study of certain branches of civil engineering, and the many and increasing applications of machinery to mining make it necessary to give much time to the theory and practice of mechanical and electrical engineering.

FIRST YEAR

See page 24.

SECOND YEAR

		First Half Year	Hours per week	
See Page			Class	Lab'y
79	Civil Eng. 23	Theory of Railroad Surveying	2	3
76	Chemistry 81	Industrial Chemistry	3	
86	Drafting 7	Structural Drafting		3
120	Physics 5	Electricity	2	
96	Mathematics 65	Calculus	5	
113	Mineralogy 1	Mineralogy	6	9
119	Phys. Educ. B	Gymnasium		2
		Total..	18	17
		Second Half Year		
74	Chemistry 66	Quantitative Analysis	3	15
76	Chemistry 82	Industrial Chemistry	3	
87	Elect. Eng. 2	Elements of the Dynamo	2	
93	Geology 6	General Geology	6	
120	Mechanics 102	Analytical Mechanics	5	
119	Phys. Educ. B	Gymnasium		2
		Total..	19	17

SUMMER WORK: Civil Eng. 27s and 28s, Practical Surveying (eight weeks).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
80	Civil Eng. 53	Resistance of Materials	5	3
80	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
75	Chemistry 69	Assaying	2	9
94	Geology 105	Economic Geology	3	
96	Mech. Eng. 13	Steam Power Machinery	3	
96	Mech. Eng. 17	Technical Thermodynamics	2	
114	Mining 51	Excavation and Tunneling	3	
		Total..	18	15
		Second Half Year		
80	Civil Eng. 54	Resistance of Materials—problem work		3
82	Civil Eng. 64	Graphic Statics	1	3
88	Elect. Eng. 72	Direct Current Laboratory		3
88	Elect. Eng. 4	Electric Distribution	2	
93	Geology 4	Petrography (6 hrs. for 2 months)		3
94	Geology 106	Economic Geology	3	
96	Mech. Eng. 14	Steam Power Machinery	3	
106	Mech. Eng. 76	Experimental Mechanical Engineering	1	3
114	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 mos.)		3
114	Mining 52	Boring & Shaft Sinking	2	
115	Mining 54	Methods of Mining	3	
		Total..	15	18

SUMMER WORK: Field work, Mining, Metallurgy, and Geology (8 to 10 weeks).

FOURTH YEAR

		First Half Year		
88	Elect. Eng. 75	Alternating Current Laboratory	1	3
95	Geology 201	Petrography (elective)		
108	Metallurgy 101, 111	Introduction and Metallurgy of Copper	3	
109	Metallurgy 131, 141	Electro-Metallurgy and Iron and Steel	2	
110	Mining 71	Mine Plant	3	
115	Mining 73	Mine Constructions	1	
116	Mining 75	Design of Mine Plant		12
116	Mining 81	Ore Dressing	4	
117	Mining 91	Mine Administration and Accounts	2	
		Total..	16	15
		Second Half Year		
79	Civil Eng. 76	Hydraulics	2	
93	Geology 16	Paleontology (elective)		
94	Geology 110	Geological Surveys	2	
104	Mech. Eng. 74	Gas Power Machinery	2	
112	Metallurgy 72	Metallurgical Laboratory (10 afts)		2
109	Metallurgy 122	Metallurgy of Gold, Silver, etc.	3	
115	Mining 56	Mine Engineering	3	
115	Mining 72	Mine Plant	3	
116	Mining 78	Thesis		12
116	Mining 80	Mill Constructions	1	
117	Mining 82	Ore Dressing (Lab.)—(afts. of 3 weeks)		3
117	Mining 94	Mining Law	2	
		Total..	18	17

METALLURGICAL ENGINEERING

General Statement

The primary aim of the four-year course leading to the degree of Metallurgical Engineer is to begin the training of students to take, first, minor administrative positions in metallurgical works, or positions in analytical, metallographic, or testing laboratories of these works; and later to take complete charge of metallurgical and allied industries. Great stress is laid on the original planning and executing of work, under constant criticism and discussion from the teachers.

Much importance is attached to a thorough training in fundamental subjects, especially in mathematics, chemistry, physics, geology, mineralogy, and engineering. Later in the course attention is devoted to the higher branches of engineering and chemistry and to important courses in mining engineering which are considered necessary.

In studying these general subjects their applications to metallurgical and like manufacture are kept in view, so as to train the student for the work before him.

The instruction in metallurgy is based on the most advanced practice in science of to-day and covers the ground from the introductory courses in metallurgy to the special advanced courses in the various branches of the subject.

To graduate and other *advanced students* and properly qualified *practitioners* the department's laboratories are open under generous restrictions. *Special* students are admitted for study and work for which they are fitted.

Location and Equipment

Location. New York and the adjacent states produce about half the pig iron and coal, and treat over 40 per cent. of the total value of the mineral product of the whole country.

Metallurgical Establishments Accessible. Some of the most instructive and advanced iron, steel, copper, lead, zinc, and electrolytic works, where many phases of the best metallurgical practice may be studied, are accessible to students. Some of these works are among the best in the world. A little farther off are the natural gas and oil fields, pyrite deposits, granite, and marble quarries of the east. The summer classes visit in different years metallurgical establishments in all parts of the country, including the extreme west and south.

Building. The department occupies about half of the new School of Mines Building generously given by Adolph Lewisohn, Esq., and described on p. 26.

Collections. There are large and growing collections of lecture diagrams; of models and working drawings of metallurgical furnaces and machinery; of apparatus for lecture demonstration and illustration of metallurgical principles and processes; and a very large collection of metallurgical specimens and suites, with descriptive and explanatory notes.

Metallurgical Laboratories. Of these there are three. They serve four chief purposes: (1) to give skill in the use of the instruments of precision of the art; (2) to teach the underlying principles of metallurgy and give familiarity with the conditions, especially as to high temperature, under which metallurgical operations must be carried on, and the use of the principal types of furnaces and other metallurgical apparatus, or in short "Analytical metallurgy"; (3) to give some acquaintance with certain industrial metallurgical processes, or what may be called "Applied metallurgy"; and (4) to give advanced students and qualified practitioners the means of making metallurgical and metallographic researches.

The Instruments of Precision. The students acquire skill with the thermo-electric pyrometer, some industrial and some autographic, with the Wanner optical and the Fery radiation pyrometer, besides which they have the opportunity of using the Mesuré and Noel (Ducretet) and the Le Chatelier optical and the Calorimetric one of Siemens. There are ammeters and voltmeters for controlling the electric furnaces; sclerometers for measuring hardness; Fremont and Brinell impact testing machines; a tensile testing machine; a Berthelot calorimeter for testing fuels; and many other instruments.

The metal working shop has power-driven machines for cutting specimens, etc.

Most of the furnaces are gas-fired, and those furnaces which are intended for precise work are heated by electric resistance.

Non-Ferrous and Electro-Metallurgical Laboratory. A. For wet and dry metallurgy, the extraction, refining, and alloying of the non-ferrous metals, there are ore roasting furnaces; gas-fired crucible furnaces; assay muffle furnaces; a high temperature forge; cyanide plants; a filter press; amalgamating pans; a chlorinating barrel; ball mills; two desilverization kettles; and pyrometers.

B. For electro-metallurgy, the electrical recovery, deposition, refining, and alloying of metals, there are storage batteries; electrolytic refining vats; and electric furnaces of the Moissan arc, Borchers arc and resistance types.

The Iron and Steel Laboratory. Here there are electric and double muffle gas furnaces especially designed for this laboratory, in which many full-sized tensile test bars may simultaneously be heated to any temperature up to 1300° C., with uniformity and precision; gas and direct-fired crucible furnaces; gas forges; many special furnaces; and

small power-driven rolls for studying the influence of the conditions of rolling on the properties of metals.

The Metallographic Laboratories, for the microscopic and pyrometric study of metals, mattes, slags, etc., in which every student in metallurgical engineering has to become skillful, has microscopes of the Leitz, Le Chatelier, Swift, Beck, and other types; equipment for illumination and photography; electric resistance furnaces of different types; portable gas furnaces; and pyrometers.

An Analytical Laboratory in which the students apply to their own metallurgical researches the methods of chemical analysis already learned in the Department of Chemistry (p. 71).

Supplies. There is a large stock of ores, irons, steels, alloys, refractory materials, fluxes, etc., which may be used for investigations.

The Metallurgical Library, containing about fifteen hundred volumes of metallurgical treatises, text-books, periodicals, etc., is open to all students, and to others properly introduced. Books may be borrowed under suitable restriction.

The undergraduate instruction consists of (1) class-room work, lectures, conferences, study of text-books, etc. (see p. 34), (2) general laboratory work in metallurgy (see below); (3) training in planning and executing original research; (4) summer courses and other visits to industrial metallurgical works.

The *graduate instruction* consists primarily of original research either in the departmental laboratories, in industrial works, or by study (see p. 112).

Metallurgical Laboratory Instruction

In order to become familiar with a wide range of the conditions and principles of metallurgy, the student makes many experiments, each illustrating, testing, or aiming to discover some one or more metallurgical principles or reactions, or the conditions which permit a given reaction to occur. He must, in general, after each experiment enunciate briefly in writing the law to which his results point, or indicate how far those results severally and collectively support or oppose a given proposition.

These experiments relate chiefly to such subjects as the influence of thermal treatment on the properties and microstructure of metals and alloys, especially iron and steel; the determination of melting points and other temperatures; the relation between the composition of slags and their fusibility; the influence of fluxes; the behavior of refractory materials at high temperatures, either alone or in contact with different slags; the temperature limits and the reactions of roasting operations; the influence of various bodies on the reactions which take place in roasting, in the cyanide process, in the chlorination process, and in pan amalgamation; the interaction of carbon and molten oxides, sulphides, silicates, etc., etc.

Metallurgical Thesis

Before entering the fourth year, students are assigned subjects for their thesis work which is covered by the courses in metallurgical plant construction (course 177) and thesis proper (course 78). In the former, the students are assigned problems in metallurgical plant construction and are required to design plants, or portions of them, for the purpose of treating certain classes of ores and accomplishing definite results. The field work of the preceding summer furnishes data which is supplemented by reading technical literature and investigations. The work is under the personal supervision of the instructor, and is carried on mainly in the drafting room of the department. In the thesis work proper, the student is given a problem relating to metallurgical operations which requires special investigation in the laboratories and knowledge of metallurgical principles, and especially of chemical reaction as applied to metallurgy. After a careful study of the subject and formulating a specific plan for carrying out the desired work, he executes an investigation along the lines thus planned, and in his graduating thesis describes his experiments and results in detail, summarizes them in tables and diagrams, and shows briefly and clearly what their answer to his problem is. The course in metallurgical investigations (Course 175) is for the purpose of instructing the student in conferences the proper methods of carrying on work outlined above.

SUMMER COURSES

Summer Courses in Metallurgy—No. 62s for mining engineers consisting of visits to non-ferrous metallurgical plants for a period of one week.

For metallurgical engineers the summer course lasts six weeks and includes No. 64s, visits to iron and steel metallurgical plants, and 66s, visits to plants for other metals. On these trips, which cover the practice in both the east and the west, the students are instructed in the actual metallurgical operations as carried on in the field. A prominent part of these courses consists of work such as making written descriptions of the processes, and sketches of the furnaces and other apparatus, with dimensions, usually from the student's own estimate; explaining the principles on which the processes rest, the reasons for the special shapes and sizes of the apparatus, the chief technical difficulties, how they are overcome, and by what tests the processes are controlled; giving the number of men, and, as far as practicable, the consumption of fuel and other materials, the thoroughness of

recovery of the metal sought, etc. From an imaginary set of prices and wages the students have to calculate the cost and profit of certain operations.

Summer Courses in Surveying—These courses are conducted during the summer vacation after the first and second year at a large farm owned by the University near Litchfield, Conn. About thirteen weeks' attendance is required of the class. For full description of this work see page 44.

Summer Courses in Geology—After the third year at least one week is devoted to practical field geology. For details see page 94.

Metallurgical Excursions—Open to students in metallurgical engineering only, to the metallurgical works near the University. At stated times excursions to the neighboring foundries, machine shops, mines, and other points of interest are made, the students attending these excursions in squads of such a size that proper individual instruction can be given to each member of the squad.

Other Departments

Information as to instruction and the equipment available for students of Mining and Metallurgy in other departments of the University is to be found in this pamphlet as follows:

Chemistry and Assaying, page 71; Civil Engineering and Surveying, page 78; Electrical Engineering, page 87; Geology, page 93; Mathematics, page 95; Mechanical Engineering, page 96; Mineralogy, page 113; Mining, page 114; Physics and Mechanics, page 119.

COURSE LEADING TO THE DEGREE OF METALLURGICAL ENGINEER

This course, which covers four years, is intended for those who expect to follow metallurgical work and become trained metallurgists in any of the branches of the profession. For the first two years much attention is paid to a thorough training in fundamental subjects, especially in mathematics, chemistry, physics, geology, mineralogy, and preliminary courses in engineering. In the third year instruction in metallurgy begins both by lectures and in the laboratories, while courses in engineering, especially mechanical engineering, chemistry, and geology, are also provided for. The fourth year is devoted largely to advanced courses in metallurgy, and great stress is laid on giving, by laboratory work, familiarity with difficult high temperature conditions of metallurgy, skill in microscopy and pyrometry and training in execution and in the interpretation of the results developed. At the same time attention is devoted to the higher branches of engineering and chemistry and to important courses in mining engineering which are considered necessary.

In the summer work, carefully arranged courses in general surveying, in railroad work, geological field work, and visits to metallurgical works are provided for. In the six weeks' summer courses at metallurgical works, the students are required to carefully study processes, make dimension sketches of furnaces and mills, and by observation and instruction are given a thorough understanding of metallurgical operations as conducted at the present time.

FIRST YEAR

See page 24

SECOND YEAR

			Hours per wee	
		First Half Year		
See Page			Class	Lab'y
79	Civil Eng. 23	Theory of Railroad Surveying	2	3
76	Chemistry 81	Industrial Chemistry	3	
120	Physics 5	Electricity	2	
96	Mathematics 65	Calculus	5	
114	Mineralogy 7	Mineralogy	6	6
119	Phys. Educ. B.	Gymnasium		2
120	Physics 43	Physical Laboratory		6
		Total..	18	17
		Second Half Year		
74	Chemistry 66	Quantitative Analysis	3	12
76	Chemistry 82	Industrial Chemistry	3	
86	Drafting 8	Structural Drafting		3
87	Elect. Eng. 2	Elements of the Dynamo	2	
93	Geology 6	General Geology	6	
120	Mechanics 102	Analytical Mechanics	5	
119	Phys. Educ. B.	Gymnasium		2
		Total..	19	17

SUMMER COURSES: Surveying Practice 5 weeks (Civil Eng. 27S).
Surveying Practice 3 weeks (Civil Eng. 28S).

THIRD YEAR

See Page			Hours per week: Class	Hours per week: Lab'y
		First Half Year		
80	Civil Eng. 53	Resistance of Materials	5	3
75	Chemistry 69	Assaying	2	9
94	Geology 105	Economic Geology	3	
96	Mech. Eng. 13	Steam Power Machinery	3	
96	Mech. Eng. 17	Technical Thermodynamics	2	
108	Metallurgy 101	Introduction to Metallurgy	1	
108	Metallurgy 111	Metallurgy of Copper	2	
112	Metallurgy 171	Metallurgical Laboratory		6
		Total..	18	18
		Second Half Year		
80	Civil Eng. 54	Resistance of Materials—Prob. & Testing Lab. Work		6
82	Civil Eng. 64	Graphic Statics	1	3
88	Elect. Eng. 72	Direct Current Laboratory		3
88	Elect. Eng. 4	Electric Distribution	2	
90	Geology 106	Economic Geology	3	
96	Mech. Eng. 14	Steam Power Machinery	3	
106	Mech. Eng. 76	Experimental Mech. Engineering	1	3
109	Metallurgy 122	Metallurgy of Lead, Silver, Gold and Zinc	3	
115	Mining 54	Methods of Mining	3	
		Total..	16	15

SUMMER COURSES: Non-ferrous Works Visits 3 weeks (Met. 66S). Iron and Steel Works Visits 3 weeks (Met. 64S). Geology Field Work 1 week (Geol 112S).

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	3
88	Elect. Eng. 75	Alternating Current Laboratory	1	3
109	Metal'gy 131	Metallurgy of Iron and Steel (½ term)	1	
110	Metal'gy 141	Electro-metallurgy—(½ term)	1	
111	Metal'gy 151	Constitution of Alloys—3 hrs. for 10wks.	2	
112	Metallurgy 175	Metallurgical Investigation	1	
112	Metallurgy 177	Metallurgical Plant Construction		12
116	Mining 73	Mine Constructions	1	
117	Mining 81	Ore Dressing	4	
117	Mining 91	Mine Administration and Accounts	2	
		Total..	16	18
		Second Half Year		
83	Civil Eng. 76	Hydraulics	2	
71	Chemistry 122	Physical Chemistry	3	
104	Mech. Eng. 72	Gas Power Machinery	2	3
112	Metallurgy 78	Thesis		12
109	Metal'gy 118	Advanced Metallurgy of Copper	1	
109	Metal'gy 128	Advanced Metallurgy of Lead, etc.	1	
110	Metallurgy 134	Metallurgy of Iron and Steel (optional)	1	
110	Metal'gy 138	Advanced Metal'gy of Iron and Steel	1	
111	Metal'gy 148	Advanced Electrometallurgy	1	
116	Mining 80	Mill Constructions	1	
117	Mining 82	Ore Dressing—5 afts. for 3 weeks		3
117	Mining 94	Mining Law	2	
		Total..	15	18

CIVIL ENGINEERING

General Statement

The four-year course leading to the degree of Civil Engineer is designed to afford a thorough analytical training, as well as numerous and extended practical exercises in those matters which pertain to the profession of the civil engineer in relation to all classes of structures and public works and in connection with the various developments and applications of power by the use of steam, electric, water, and air motors. This course is also designed to be an educational preparation for those duties or functions of an executive character whose discharge in connection with the management of public or other works requires, or is rendered more efficient through, a thorough knowledge of civil engineering. The breadth and nature of this educational training adapts it no less efficiently to the purposes of those who intend to follow callings not of an engineering character but which may be related more or less to manufacturing, to structural matters, or to the development and application of power. The theoretical portion of the instruction is based largely upon the courses given in the departments of Mathematics, Mechanics, and Physics, and the results obtained are applied to practical engineering work. Special stress is laid upon the design by the student of the various structures and machines which the civil engineer is called upon to construct in the practice of his profession. The instruction is given by lectures, demonstrations by the student, and frequent conferences, co-ordinate with which the work of design is continuously carried on. It covers comprehensively the subjects of surveying, road and railroad engineering, water supplies of cities and towns, irrigation, sanitary engineering, including sewage disposal, both graphic and analytic treatment of all metallic structures, foundations, retaining and reservoir walls, high masonry dams, sewer systems, hydraulic engineering, rivers and harbors, pumping engines, hydraulic, steam and electric motors.

Ample facilities are afforded for post-graduate students in civil engineering, and special students are admitted to various engineering courses of the department upon evidence of proper qualifications.

Equipment

The school possesses an unusually full equipment of engineers' and solar transits, levels, plane tables, compasses, and all accessories, as well as smaller instruments. Current meters, book gauges, and floats of discharge of, rivers and canals. A complete set of sections of iron and various types are also used in making observations on the flow in, and

steel shapes, models and photographs of engineering works, together with working plans of the latter, are in the department for the use of students. The hydraulic laboratory affords opportunity for the practical operations of measuring the discharge through weirs and other orifices, the flow through open channels and closed pipes, frictional and other resistances in pipes and open channels, as well as for meter gaugings, and for general hydraulic investigations. The testing work in the mechanical laboratory includes the complete tests of various structural materials in tension, compression, bending, and torsion, including the observation and digesting of all corresponding data.

A cement-testing laboratory is fully equipped with testing machines, briquette molds, tanks, and other apparatus requisite for all classes of investigations in the nature and physical properties of cements and cement mortars.

A complete laboratory for the testing of road materials has been established and is constantly in use for investigations connected with materials suitable for road building. The facilities offered by the laboratory are full and sufficient to make all tests required to determine resistance to abrasion, classification of sand, gravel and broken stone and the cementing power of all qualities of road materials. The laboratory is at the service of students and is used by them, both for the ordinary prosecution of studies to which the determination of results is related and for the purposes of thesis work, and other similar investigations.

The Materials Testing Laboratory is located at the north end of the main floor of the Engineering Building. It is fully equipped with modern appliances for the conduct of tests upon all structural materials. There are seven testing machines varying in capacity from 600 lbs. to 400,000 lbs., representing all American types, including a 150,000-lb. Emery hydraulic power machine, which is a standard of accuracy, and the refinement of mechanical construction. These machines are suited to make tension, compression, transverse and torsion tests upon metals, also to make all desired tests upon building materials, such as timber, stone, brick, concrete blocks or concrete-steel beams, columns, partition blocks, and all built up materials.

The laboratory is also liberally supplied with a large assortment of extensometers, deflectometers, micrometers, gauges, and similar instruments of precision for measurement of test pieces.

Other apparatus such as delicate scales of different sizes for use in absorption and freezing tests on building materials, also pyrometers and furnaces for the conduct of fire tests upon all kinds of fire-resisting materials are available. A complete fire-testing station is also available to the Department of Civil Engineering. This is under control of the officers of the testing laboratory, and is equipped with several large test buildings and all necessary apparatus and appliances for making regulation fire, load and water tests upon walls, floors, parti-

tions, etc., in full size units, as prescribed by the building codes of New York and Philadelphia. Commercial work of this character, as well as in the laboratory, is continually in progress, and is open to student observation at all times, thus keeping them in touch with the practical demands of the hour in this line of investigation work.

General Statement of the Summer Courses in Surveying and Geodesy at Camp Columbia, Morris, Conn.

The instruction in Surveying given by the Department of Civil Engineering consists of lectures, recitations and problem work, supplemented by instrumental practice in field work, and office work in computation and mapping. The general lectures and recitations are given at the University. The field practice is given during the three summer vacations of the regular four-year course. The subject of Geodesy is given by the Department of Astronomy, and the practical work connected therewith is done under the supervision of that department by students in Civil Engineering during a portion of five weeks of the summer vacation between the third and fourth years. The theory of Plane Surveying, including Railroad Surveying, is given by the Department of Civil Engineering. The field practice is conducted under the direction of the Department at Camp Columbia, a point in the country near Litchfield, Conn., where ample facilities are provided for all requisite operations, and where the topography and climate are admirably adapted to the practical work of surveying. Five weeks' continuous attendance is required of all students in the Schools of Mines, Engineering and Chemistry during the summer between the first and second years. (See C. E. 15, page 79.) Five weeks' additional attendance is required of all students in Civil Engineering (see C. E. 25, page 79), and eight weeks of all students in Metallurgy, and eight weeks of all students in Mining (see C. E. 27 and 28, page 80) during the summer between the second and third years. Nine weeks' continuous attendance is required of all students in Civil Engineering during the summer between the third and fourth years (see C. E. 26, Astronomy 107 and C. E. 71, pages 79, 70, 82). During the summer of 1910 the Summer Courses in Surveying and Geodesy will be in session about fifteen weeks.

No student taking these courses will be excused from any part of any course on account of work done elsewhere, unless that work has been done under the immediate direction of an instructor of an institution which grants degrees in Mining or Civil Engineering. In no case will credit be given except upon the evidence of field-notes, maps, and reports presented to the Professor in charge of the courses.

Two examinations will be held at Camp Columbia for new students, special students and students who fail to receive a mark of 5.0 (this is not a passing mark in C. E. 2, but entitles the student to take Course

C. E. 15) or more in C. E. 2, and this examination must be taken by these men before they begin field work. The first examination will be held July 1 for students who desire to enter with Div. G, and the second one August 5, 1910, for students who desire to enter with Div. I.

The University provides houses or tents having elevated floors, furnished with cots and drafting tables. There are also provided a dining hall and bath house. Arrangements may be made for laundry work to be done in the neighborhood. A supply of drafting materials (not instruments) is kept on sale. Especial attention is given to the wholesome and substantial character of the table.

The cost of board is $6.75 per week and is charged against the individual deposits. The account against each student is reckoned from the day announced for his division to assemble. No allowances or reductions are made for absences of less than one week, and then only in the event of notice having been given and excuse granted by the officer in charge at least one day in advance of the beginning of such absence.

Each student intending to take work in these courses must register with the Registrar of the University not later than May 10. Subsequent changes in plans must be reported at once.

Every student must be present on the day appointed for his division to assemble, unless other arrangements have been made with the officer in charge. Failure to comply with this regulation may be sufficient cause to refuse the applicant's admission to the courses.

Deposits for Camp Expenses

Every student before starting for Camp, and at the same time the fees for the summer session in surveying are paid, shall make a deposit at the Bursar's office at Columbia University to meet Camp expenses, viz., board, laundry, charges for drawing material, notebooks, etc.; also to cover any damage to, breakage, or loss of instruments or Camp equipment, and transportation of self and baggage from the station to and from the Camp. The Bursar's receipt for said deposit shall be presented to the professor in charge of the summer session upon the arrival of the student in Camp.

The amounts of the deposit varies with the course or the number of courses taken and is as specified below. Students intending to take two or more courses shall deposit an amount equal to the sum total of the deposits herein specified for the respective courses. The balance of the deposit which shall remain to the credit of the student after his withdrawal from the session will be returned to him during the following October upon his application to the Bursar of Columbia University. In case the total charges exceed the deposit the student will be subject to an additional assessment.

The deposit for C. E. 15 shall be $50; for C. E. 25, $50; for C. E. 26, $20; for C. E. 27, $50; for C. E. 28, $35; for C. E. 71, $35; and for Geodesy 107, $30.

The deposit for any one *survey* of Courses 15, 25, or 27 shall be $15.

Fees

For statement concerning tuition fees and laboratory fees see page 17 of the General Announcement.

Schedule of Attendance

In 1910 the School Session opens May 28 and closes September 10.

Div. A—May 28 to July 2, 5 weeks—Course 25.
Open for all 2d, 3d, 4th year students in Civil Engineering who have completed Course 15.

Div. B—May 28 to July 2, 5 weeks—Course 27.
Open for all 2d, 3d, 4th year students in Mining Engineering and Met. Engineering who have completed Course 15.

Div. C—May 28 to July 2, 5 weeks—Course 15.
Open for all 2d, 3d and 4th year students in the Schools of Mines, Engineering, and Chemistry who have not finished Course 15.

Div. D—May 28 to July 2, 5 weeks—Course 15.
Open for 20 or 25 men of all 1st year students as assigned on basis of scholarship.

Div. E—July 2 to August 6, 5 weeks—Course 25.
Open for 2d, 3d, 4th year students in Civil Engineering who reported with Div. C or Div. D for Course 15.

Div. F—July 2 to August 6, 5 weeks—Course 27.
Open for 2d, 3d, 4th year students in Mining and Metallurgy who reported with Div. C or Div. D for Course 15.

Div. G—July 2 to August 6, 5 weeks—Course 15.
Open for 1st year students as assigned from those not assigned to Div. D and of those who do not register for the summer session in New York. (Probably 75 men.)

Div. H—July 9 to August 13, 5 weeks—Course 26 C. E. and Course 107 Astronomy.
For 3d and 4th year students in Civil Engineering who have finished Course 15 and Course 25.

Div. I—August 6 to September 10, 5 weeks—Course 15.
For 1st year students as assigned from those not assigned to Div. D or Div. G. (Special dates may be arranged for those who attend Summer Session at Columbia University in New York.)

Div. J—August 13 to September 10, 4 weeks—Course **71.**

For 3d and 4th year students in Civil Engineering who have finished Course **15,** Course **25** and Course **51-52.**

Div. K—August 13 to September 10, 4 weeks—Part of Course **25 or Course 27.**

For 2d, 3d, 4th year students in Mining, Metallurgy and Civil Engineering reported with Div. C and who withdrew with permission on July 6 to attend Summer Session at Columbia University, in New York.

Div. L—*August 13 to September 10, 4 weeks—Part of Course **15.**

For special students not heretofore registered at Columbia University but who have been in attendance at Summer Session at Columbia.

*Special students wishing to enter this course and who are not in attendance at Summer Session in New York should report August 6.

Div. M—August 20 to September 10, 3 weeks—Course **28.**

For 2d, 3d, 4th year students in Mining and Metallurgy who have finished Course **15,** Course **27** and Course **23.**

COURSE LEADING TO THE DEGREE OF CIVIL ENGINEER

The courses of study given in the Department of Civil Engineering are so formulated as to constitute broad educational training of a professional character for students intending to follow the practice of Civil Engineering or such other affiliated callings as may be based more or less upon the various branches of Civil Engineering. These courses of study can be taken more advantageously if the student has had a preliminary general training equivalent to that of an ordinary college course although that condition is not a requisite. Through these courses of study there is set forth a thorough grounding in the fundamental principles of engineering science as the first essential, supplemented, however, by constant exercises in the application of those fundamental principles to all the operations of the Civil Engineer, involving structures, machines and processes connected with the adaptation and transmission of power for industrial and other purposes.

FIRST YEAR

See page 24

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
70	Botany 7	Growth and Character of Timbers	1	3
79	Civil Eng. 21	Roads, Streets and Pavements	2	
86	Drafting 5	Graphics		6
120	Physics 5	Electricity	2	
96	Mathematics 65	Differential and Integral Calculus	5	
96	Mech. Eng. 13	Steam Power Machinery	3	
113	Mineralogy 5	Minerals of Building Stones	2	2
115	Mining 53	Excavation, Tunneling, Boring and Shaft-sinking	3	
119	Phys. Educ. B	Gymnasium		2
123	Shop Work 15	Forging and Foundry Practice		3
		Total..	18	16
Second Half Year				
76	Chemistry 82	Industrial	3	
86	Drafting 8	Structural Drafting		6
87	Elect. Eng. 2	Electrical Engineering	2	
93	Geology 18	General Geology	3	*3
96	Mech. Eng. 14	Steam Power Machinery	3	
120	Mechanics 102	Analytical Mechanics	5	
110	Metallurgy 134	Iron and Steel	2	
119	Phys. Educ. B	Gymnasium		2
120	Physics 44	Physics Laboratory		6
123	Shop Work 16	Machine-work		3
		Total..	18	18

*Saturday P.M., 1 afternoon during April and May—equivalent 1 hour.
SUMMER WORK: Practical Surveying Civil Eng. 25S—5 weeks.

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
70	Astronomy 105	Geodesy	3	
80	Civil Eng. 51	Railroad Surveying	2	3
80	Civil Eng. 53	Resistance of Materials	5	3
80	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
81	Civil Eng. 59	Sanitary Treatment, Water Supply and Sewage	2	
82	Civil Eng. 61	Theory of Trusses	2	3
96	Mech. Eng. 17	Technical Thermodynamics	2	
106	Mech. Eng. 77	Mechanical Laboratory	1	3
		Total..	17	15
		Second Half Year		
70	Astronomy 106	Geodesy	1	3
80	Civil Eng. 52	Railroad Surveying	3	3
80	Civil Eng. 54	Resistance of Materials (Problems)		3
81	Civil Eng. 58	Masonry Structures	3	3
82	Civil Eng. 62	Graphic Statics	2	3
88	Elect. Eng. 72	Direct Current Laboratory		3
88	Elect. Eng. 4	Electric Distribution	2	
96	Mech. Eng. 18	Technical Thermodynamics	2	
106	Mech. Eng. 78	Kinematics	3	
		Total..	16	18

SUMMER WORK: { Hydrographic Surveying—Civil Eng. 26S; Geodetic " —Astronomy 107S } 5 weeks.
Railroad surveying practice—Civil Eng. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
82	Civil Eng. 75	Hydraulics	4	
83	Civil Eng. 85	Foundations	2	3
83	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
83	Civil Eng. 89	Railroad Engineering	3	3
84	Civil Eng. 95	Contracts and Specifications	2	
85	Civil Eng. 99	Thesis		3
100	Mech. Eng. 41	Machine Design	1	3
104	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	14	18
		Second Half Year		
83	Civil Eng. 88	Bridges, Roofs and Buildings	2	3
83	Civil Eng. 90	Railroad Engineering	3	3
84	Civil Eng. 94	{ Design and Construction of Sewers; River and Harbor Improvement }	2	
85	Civil Eng. 98	Water Supply and Irrigation Eng.	2	
85	Civil Eng. 100	Thesis	3	6
89	Elect. Eng. 76	Alternating Current Laboratory	1	3
91	Elect. Eng. 112	Electric Railway	2	
101	Mech. Eng. 46	Hydraulic Power Machinery	3	
		Total..	18	15

COURSE IN SANITARY ENGINEERING

The course in Sanitary Engineering is a differentiation from the regular course in Civil Engineering and naturally leads, therefore, to the same degree. The first year is identical with the first year of other engineering courses, while the second year is almost identical with the regular second-year work of the course in Civil Engineering. The special extensions in sanitary work are developed in the third and fourth years. It will be found that these sanitary subjects are set forth so as to cover in a thorough and comprehensive way those special fields occupied by the sanitary engineer of the present day. They include the sanitary treatment of water supplies and sewage with special work extended both by lectures and laboratory work into biology and bacteriology, standard laboratory methods in the sanitary administration of public water supplies, drainage, heating and ventilation and the general principles of sanitary science, public health and hygiene. These sanitary specialties are of advanced character, covering the latest investigations in such special work as daily bacterial tests of potable water for public purposes, the extermination of mosquitoes and other disease-carrying insects, the improvement of public health conditions found in cities and towns, the drainage and sanitary treatment of lands and the sanitary administration of buildings and industrial establishments liable to create nuisances. A graduate, therefore, of this course is qualified to enter the advanced practice of sanitary engineering in all its special fields.

FIRST YEAR.

See page 24.

SECOND YEAR

		First Half Year	Hours per week	
See Page	Name of Course	Description of Course	Lect.	La b
70	Botany 7	Growth and Character of Timbers	1	3
79	Civil Eng. 21	Roads, Streets, and Pavements	2	
73	Chemistry 65	Quantitative Analysis	2	6
86	Drafting 5	Graphics		6
120	Physics 5	Electricity	2	
96	Math. 65	Differential and Integral Calculus	5	
96	Mech. Eng. 13	Steam Power Machinery	3	
113	Mineralogy 5	Minerals of Building Stones	2	2
119	Phys. Educ. B	Gymnasium		2
		Total..	17	19
		Second Half Year		
76	Chemistry 82	Industrial Chemistry	3	
86	Drafting 8	Structural Drafting		6
87	Elect. Eng. 2	Electrical Engineering	2	
93	Geology 18	General Geology	3	3*
120	Mechanics 102	Analytical Mechanics	5	
96	Mech. Eng. 14	Steam Power Machinery	3	
110	Metallurgy 134	Iron and Steel	2	
120	Physics 44	Physics Laboratory		6
128	Shop Work 16	Bench and Machine		3
77	Chemistry 92a	Microscopy		2*
119	Phys. Educ. B	Gymnasium		2
		Total..	18	19

* February and March—Microscopy; April and May—Geology.
SUMMER WORK: Practical Surveying C.E. 25—5 weeks.

THIRD YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
70	Astronomy 105	Geodesy	3	
123	Zoology 7	Sanitary Biology }	2	6
70	Bacteriology 101	Sanitary Bacteriology }		
80	Civil Eng. 51	Railroad Surveying	2	3
80	Civil Eng. 53	Resistance of Materials	5	3
80	Civil Eng. 53	Resistance of Materials Testing		3
81	Civil Eng. 59	Sanitary Treatment of Water Supplies and of Sewage	2	
82	Civil Eng. 61	Theory of Trusses	2	3
72	Chemistry 41	Organic Chemistry	2	
		Total..	18	18
		Second Half Year		
70	Astronomy 106	Geodesy	1	3
80	Civil Eng. 52	Railroad Surveying	3	3
80	Civil Eng. 54	Resistance of Materials		3
81	Civil Eng. 58	Masonry Structures	3	3
82	Civil Eng. 62	Graphic Statics	2	3
72	Chemistry 42	Organic Chemistry	2	
88	Elect. Eng. 72	Direct Current Laboratory		3
88	Elect. Eng. 4	Electric Distribution	2	
106	Mech. Eng. 78	Kinematics	3	
		Total..	16	18

SUMMER WORK: { Hydrographic Surveying—C. E. 26S } 5 weeks.
{ Geodetic Surveying—Astronomy 107 }
Railroad Surveying Practice, C. E. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
82	Civil Eng. 75	Hydraulics	4	
83	Civil Eng. 85	Foundations	2	3
83	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
83	Civil Eng. 89	Railroad Engineering	3	3
84	Civil Eng. 95	Contracts and Specifications	2	
81	Civil Eng. 55	Physical and Biological Water Analysis		6
81	Civil Eng. 57a	Statistics and Interpretation of Water Analyses }	2	
81	Civil Eng. 57b	Drainage of Marshes and Lowlands }		
96	Mech. Eng. 17	Technical Thermodynamics	2	
109	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	17	18
		Second Half Year		
83	Civil Eng. 90	Railroad Engineering	3	3
84	Civil Eng. 94	Sewers, and River and Harbor Imp.	2	
85	Civil Eng. 98	Water Supply and Irrigation Eng.	2	
84	Civil Eng. 96	Principles of Sanitary Science, Public Health and Hygiene	3	
85	Civil Eng. 100	Thesis		9
89	Elect. Eng. 76	Alternating Current Laboratory	1	3
106	Mech. Eng. 76	Mechanical Laboratory	1	3
106	Mech. Eng. 82	Heating and Ventilation	3	
		Total..	15	18

ELECTRICAL ENGINEERING

General Statement

The prescribed course leading to the degree of Electrical Engineer (E.E.) requires four years for its completion, and is designed for the education of those who intend to practice the profession of Electrical Engineering, either as engineers, managers, experts in industrial enterprises or as teachers in colleges or technical schools.

The instruction comprises the important branches of theoretical and applied electricity, also the fundamental and collateral subjects, which have been found by experience to be required by the electrical engineer, as, for example, mathematics, physics, chemistry, drawing, mechanical engineering, including boilers, gas producers, engines, turbines, hydraulic developments, transmission devices and shop work, also such general engineering subjects as construction in wood, masonry, iron and steel.

The graduate in Electrical Engineering is accordingly provided not only with a thorough knowledge of the principles and applications of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for the demands likely to be made upon him in connection with the practice of his profession.

The instruction is by lectures and recitations as well as by laboratory, work-shop and drawing-room practice, with periodic visits to the numerous and important electrical factories, power stations and other establishments in and about New York City.

Equipment

The offices, laboratories, museums and lecture rooms of the Electrical Engineering Department are in the southern portion of the Engineering Building. The laboratories located in the basement contain direct and alternating current machinery and apparatus. The smaller machines are mounted upon heavy tables, thus raising them to a convenient height and affording space for instruments and note-books. To further simplify the work, the machines have been assembled into unit sets, a motor being provided for each generator, so that the experimental work

of one squad of students is entirely independent of that of other squads.

The direct current laboratory contains constant potential and constant current generators, motor-dynamos, as well as various types of stationary and railway motors, aggregating forty machines ranging in capacity from 1 to 35 kilowatts and of standard voltages from 115 to 550. Two 10 and two 5 k.w. generator sets with complete switchboards, carrying many measuring instruments enable various experiments to be performed by the students on the parallel operation of generators. The constant current equipment includes a dynamo, standard switchboard and series lamp circuits. A working standardization equipment for the calibration of all measuring instruments is installed in this laboratory, and prior to any tests the students are required to check their various instruments. About seventy electrical measuring instruments are employed in this laboratory, comprising ammeters and voltmeters with various scale ranges, also speed indicators, transmission and absorption dynamometers. This laboratory is provided with a set of machine and hand tools employed in the repair of the various pieces of apparatus.

The alternating current apparatus, located in the adjoining room, comprises one single-phase alternator of 10 k.w. capacity and two three-phase alternators of 10 and 45 k.w. capacity, respectively; two 10 kilowatt synchronous motors and rotary converts operative on single-phase or two-phase circuits; two single-phase and four polyphase induction motors varying in capacity from 1 to 10 horse-power; constant potential transformers of various capacities; phase transformers for converting two-phase to three-phase currents and *vice versa;* a constant current transformer equipment of 5 kilowatts capacity with its control board, circuits and lamps; an induction regulator of 5 kilowatts and a mercury arc rectifier of the same capacity. Each of the various alternators is provided with its own driving motor, so that the speed voltage and frequency may be altered as desired. This laboratory equipment includes a complete switchboard for the operation, control, and testing of the rotary converters used as such or as alternators; also a special polyphase circuit measuring board and about forty instruments for the measurement of alternating voltage, current and power. The alternating current ammeters and voltmeters are of various capacities, ranging from fractional values up to 2,000 amperes and 600 volts respectively, also wattmeters up to 1,200 kilowatts range. The instrument equipment further includes several frequency indicators, synchronizers and power factor meters as well as a complete oscillograph and an ondograph for the determination of wave forms, phase relations, etc.

The lecture rooms of the department, capable of seating about 250 students in all, and the museum are located on the first floor of the building. The lecture rooms are provided with direct-current, single-

phase and polyphase electrical circuits and projection lanterns so that the lectures may be accompanied by experimental demonstrations and illustrations. The museum contains many pieces of apparatus and parts of machines used in connection with the lectures, such as specimens of pole line insulators, conduit material, rail sections, rail bonds, insulated cables and materials employed in transmission line and electric railway construction. Also various pieces of apparatus employed in telegraphy and telephony; forms of storage battery plates, samples of products obtained by electro-chemical actions, elementary electrical apparatus, etc.; pieces of electrical machinery, such as armature laminations, field and armature coils, commutator sections, brush holders, brushes, insulating materials; small models of various types of generators and motors; numerous forms of incandescent and arc lamps, lamp mechanisms, carbons and electrodes; lighting arresters, line protecting devices and measuring instruments.

On the third floor of the building are located the large instrument laboratory, the departmental drawing-room and the studies of the officers. The laboratory contains tables upon which the various instruments are permanently set up, ready for use. These include many different forms of galvanometers, three ampere balances with scale ranges from .01 to 600 amperes, two dynamometers with ranges of 1 to 200 amperes respectively, a Standard Weston laboratory voltmeter having a range from .01 to 750 volts and a Standard Weston laboratory millivoltmeter with a set of shunts reading up to 500 amperes, Westinghouse precision watt and voltmeters and two very accurate potentiometers. The equipment further comprises apparatus for the exact measurement of resistance, inductance, permeability, hysteresis, and magnetic leakage. This laboratory is supplied with electrical energy from special sources, so that fluctuations do not cause uncertainty in the various measurements. For the direct current work special storage batteries supply potentials up to 250 volts and others have current capacity of 1,000 ampere-hours. For tests requiring small values of alternating currents a special alternator is operated. This laboratory also contains high tension testing apparatus, consisting of two 50,000 volt transformers of 5 and 10 kilowatts capacity respectively, two 10,000 volt transformers of 5 and 10 kilowatts respectively, and one 5,000 volt transformer of 5 kilowatt output. These transformers are supplied with necessary protective and measuring devices and all are designed for operation on 60 cycle circuits. This instrument laboratory is also equipped with several forms of standard integrating and recording watt-hour meters employed in connection with the standardization of consumers' electric meters for the Department of Water Supply, Gas, and Electricity of the City of New York.

The photometric testing laboratory of this Department is situated in the basement of Havemeyer Hall and is equipped with a Lümmer-

Brodhun screen photometer for incandescent lamp testing, a Bunsen screen photometer with a meter prover for gas light testing and a Weber photometer, which is adaptable for arc lamp testing or for the determination of general illumination.

COURSE LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

The objects for which the regular four years' course in Electrical Engineering is designed and the education which it is intended to give are fully set forth in the "General Statement" of the Electrical Engineering Department, found on page 52.

The actual curriculum, including the various requirements which must be fulfilled in order to obtain the E. E. degree, are named in the following list of studies for each year, the character of each subject or requirement being explained more fully in the Departmental Statement referred to. The first two years of the course are devoted to the fundamental subjects, including mathematics, physics, chemistry, mechanics, drawing and certain electrical and mechanical engineering subjects which are elementary or introductory in character.

These fundamental and introductory subjects are intended to lay a broad and substantial foundation upon which the more specialized professional instruction of the third and fourth years is based. Even in these later years theoretical subjects, such as thermodynamics and electro-mechanics, are included and given most careful attention.

FIRST YEAR

See page 24

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
73	Chemistry 65	Quantitative Analysis	2	6
76	Chemistry 81	Industrial Chemistry	3	
120	Physics 5	Electricity	2	
96	Mathematics 65	Differential and Integral Calculus	5	
96	Mech. Eng. 13	Steam Power Machinery	3	
119	Phys. Educ. B	Gymnasium		2
120	Physics 43	Physical Laboratory		6
120	Physics 105	Physical Measurements	2	
123	Shop Work 13	Machine Work		3
		Total..	17	17
Second Half Year				
72	Chemistry 38	Physical Chemistry	2	
76	Chemistry 82	Industrial Chemistry	3	
86	Drafting 6	Graphics	1	6
86	Drafting 8	Structural and Machine Drawing		6
87	Elect. Eng. 2	Elements of the Dynamo	2	
96	Mech. Eng. 14	Steam Power Machinery	3	
120	Mechanics 102	Analytical Mechanics	5	
110	Metallurgy 134	Metallurgy of Iron and Steel	2	
119	Phys. Educ. B	Gymnasium		2
123	Shop Work 14	Machine Work		3
		Total..	18	17
Summer memoir.				

THIRD YEAR

See Page		First Half Year	Hours per week Class	Lab'y
80	Civil Eng. 53	Resistance of Materials	5	3
80	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
77	Civil Eng. 77	Hydraulics	2	
89	Elect. Eng. 101	Dynamo and Motor Practice	2	
91	Elect. Eng. 173	Direct Current Laboratory		6
96	Mech. Eng. 17	Technical Thermodynamics	2	
100	Mech. Eng. 41	Machine Design	1	3
121	Mechanics 105	Thermodynamics	2	
121	Mechanics 107	Theory of Dynamo and Motor	2	
		Total..	16	15
		Second Half Year		
86	Economics 2	Economics	3	
88	Elect. Eng. 52	Design of Direct Current Machinery	2	3
90	Elect. Eng. 104	Electrical Distribution	3	
91	Elect. Eng. 174	Direct Current Laboratory		3
96	Mech. Eng. 18	Technical Thermodynamics	2	
96	Mech. Eng. 36	Kinematics of Machinery		6
106	Mech. Eng. 76	Experimental Mech. Eng.	1	3
121	Mechanics 108	Theory of Dynamo and Motor	3	
		Total..	14	15
		Summer memoir.		

FOURTH YEAR

		First Half Year		
78	Chemistry 183	Electrochemistry	2	3
89	Elect. Eng. 103	Electric Power	3	
90	Elect. Eng. 105	Electrical Plants	3	
91	Elect. Eng. 175	Alternating Current Lab.	1	6
92	Elect. Eng. 177	Instrument Laboratory	1	6
101	Mech. Eng. 53	Steam Turbines	2	
106	Mech. Eng. 77	Experimental Mechanical Laboratory	1	3
121	Mechanics 109	Theory of Alternators & Transformers	4	
		Total.	17	18
		Second Half Year		
	Elect. Eng.	Preparation of Reports		3
88	Elect. Eng. 54	Design of Alt. Current Machinery	2	3
89	Elect. Eng. 98	Graduation Thesis (Optional)		
90	Elect. Eng. 106	Management of Electric Plants	2	
90	Elect. Eng. 110	Telegraph and Telephone	2	
91	Elect. Eng. 112	Electric Railways	2	
91	Elect. Eng. 176	Alternating Current Laboratory	1	8
102	Mech. Eng. 56	Water Power Installations	1	
103	Mech. Eng. 60	Hydraulic Laboratory		3
106	Mech. Eng. 72	Gas Power Machinery	2	3
121	Mechanics 110	Theory of Variable Currents	2	
		Total..	14	20

MECHANICAL ENGINEERING

General Statement

The regular four-year course, leading to the degree of Mechanical Engineer, offers a thorough basic training in the design, construction, manufacture and operation of all classes of standard and special machinery, mills, shops, factories and power plants, as well as in the technical and executive management of the dependent industries. To this end the course of instruction is as broad as is consistent with the directness of its purpose. The Mechanical Engineer must not only be grounded in the fundamental scientific basis of his profession, and so trained as to be capable of applying this to both the technical and commercial aspects of industrial problems, but his immediate usefulness upon graduation demands that a considerable portion of the instruction be concerned with the practical application of the principles taught.

The course begins with a thorough training in mathematics, physics and chemistry as a foundation for the appropriate technical work, which is developed along several parallel lines. Applications of these fundamental sciences to the physical properties of the materials of construction, especially the metals and their practical manipulation, lead through the courses in metallurgy, mechanics, resistance of materials, shop processes, the materials testing laboratory, drafting and kinematics to the principles of design, which are fixed by application to the design of special machinery for the execution of any specified manufacturing process and to certain standard machinery, such as steam and gas engines and turbine water wheels. The principles underlying the performance of machinery are developed by courses in thermodynamics, mechanics and hydraulics and the experimental laboratory and are fixed by analysis of machinery for steam and gas power, pumping, compressing, refrigerating, mechanical handling of materials and their most important applications. The instruction in the performance, design and manufacture of machines and power units in the class-room and laboratory, supplemented by frequent visits to power plants and factories, is the basis of the work on the design of plants and mills.

Throughout the instruction the student is thrown as much as possible on his own resources, encouraged to use such knowledge as he possesses, to read standard authorities and to make comparisons between the existing data on various subjects and with the results of theoretical computations. In the experimental work special stress is laid upon this as a means for the development of that initiative, executive ability and spirit of investigation so necessary for the successful practice of the

profession, which is one long series of new problems demanding solution. The commercial and industrial phases of the technical subjects are dwelt upon throughout the entire course of instruction, and particular attention is given to labor and cost systems, works management, economy of manufacture and of power generation, economics and industrial law.

To insure a close contact between the work of the department and the practice of the profession, recognized experts are invited to conduct courses on their particular subjects, the regular officers of the department attending and subsequently holding recitations and examinations.

For a list of special lecturers and their subjects see page 8.

In addition to these regular lecturers, a list of non-resident lecturers, who deliver one or more lectures to the students on the work in their respective engineering fields will be found on pages 8, 9 and 10.

The overlapping of the Mechanical Engineering and Electrical Engineering professions makes it desirable that the Mechanical Engineer shall be thoroughly conversant with the ordinary problems of the Electrical Engineer in the generation and distribution of electric current, the characteristics of electrical machinery, and the design and installation of electrical plants. To this end students in this course receive instruction in the department of Electrical Engineering covering these subjects.

Graduate work in Mechanical Engineering is offered to students who have successfully completed the undergraduate course. This graduate work includes the more difficult applications of mechanics and thermodynamics to questions of engineering, as well as special investigations in design, experimental research, and the development of new processes of manufacture. Special students are admitted to any of the courses upon evidence of proper qualifications. Courses are also offered to students in other departments covering such instruction in Mechanical Engineering as may properly assist in the practice of their respective professions.

Equipment

Besides the usual offices, lecture rooms, drawing rooms and museum, the department is unusually well equipped with experimental laboratory facilities. These laboratories cover a floor space of some 18,500 sq. ft. and contain apparatus valued roughly at $75,000. A fairly full line of instruments for making simple measurements is always available for regular student work, and includes thermometers, pyrometers, barometers, simple and differential manometers, draft gauges, speed counters, tachometers, angular velocity meters, planimeters, Pitot tubes, water meters of piston, rotary and Venturi type, hook gauges, steam and gas meters, steam, gas, coal and oil calorimeters, flue gas analysis apparatus, scales for weighing and measuring, transmission dynamometers, Prony brakes, indicators of all types, pressure and vacuum gauges, anemometers,

mercury columns, and calibrating apparatus for all instruments. Besides these measuring devices there is a large number of pieces of special apparatus for various purposes, such as the testing of carburetors, pressures due to explosion of gas mixtures, rate of flame propagation in explosive mixtures, pressure and temperatures of vaporization of liquid fuels, loss of head in steam, air and water pipes, condensation of steam in pipes, flow of steam or water through orifices and turbine nozzles, capacity of steam traps, flash, chill, density, viscosity and carbonization of oils, friction of bearings, losses in power transmission. These various instruments and pieces of special apparatus are grouped and used in connection with a considerable number of machines of standard form. These include a standard gauge Vauclain compound locomotive, mounted on friction wheels equipped with dynamometers. This locomotive is so erected that it can be operated with its own steam, line steam or compressed air, the exhaust passing through an induced draft fan separately driven by a small steam engine. A Reynolds Allis-Corliss triple expansion engine, double eccentric type, is equipped to operate condensing and non-condensing, and is fitted with reheating receivers and may be operated with line steam or high pressure steam from the locomotive boiler. This Corliss engine has a tandem connection to three air cylinders, equipped with Gutermuth flap valves, operating three-stage with water intercoolers. A cross compound steam, two-stage air compressor of the Ingersoll-Sargent type operates in parallel with the other air compressor and with a Westinghouse simple air pump with complete air brake equipment. There is also a belt and a steam driven fan for fan investigations, together with belt and steam driven centrifugal pumps for corresponding investigation on centrifugal action of water. Besides the steam engines mentioned there are also a Westinghouse two-cylinder, single-acting; McIntosh and Seymour automatic; Sweet straight-line simple engine, besides some smaller reciprocating units, and a De Laval steam turbine, all piped to condensers for efficiency tests on wet, dry or superheated by a Foster superheater separately fired. The steam used by the engines and pumps is measured by any one of three surface condensers, Wheeler, Worthington, Allis, each with its own air and circulating pumps. The steam equipment includes also typical injectors, steam traps, feed water heaters, separators, reducing valves, safety valves, back pressure valves and other ordinary steam auxiliaries and specialties. The hydraulic work is well provided for by two large 20,000-lb. measuring tanks, fitted with swinging guide-bucket for continuous flow measurements, receiving the discharge from all the hydraulic apparatus; water channels of rectangular, trapezoidal and triangular cross section, rectangular and trapezoidal weirs, fitted to several weir tanks, of iron and wood, three impulse water wheels, one small turbine, hydraulic rams, simple, single and duplex steam

pumps, direct acting and flywheel, compound Blake pump, single acting, direct acting triple expansion duplex, low pressure Worthington pump of large capacity and low head, separately steam driven centrifugal Lawrence pump, belt driven centrifugal pump, a high pressure pump and accumulator of the Worthington type for 1500 lbs., and a second for 5000 lbs. pressure. Two hot air engines, and several internal combustion engines, including the Nash, fitted to operate on various fuels, a Hornsby-Akroyd and a Mietz and Weiss oil engine, an old and a new style Otto, an International Harvester, a Daimler boat engine are equipped for gas engine test and investigation work of great variety. From time to time other machines are secured for short periods of time for testing purposes. For the study of refrigeration there is installed a small Brunswick ammonia compression ice-making and refrigerating unit, motor driven, and a larger De La Vergne steam-driven, ice-making plant.

COURSE LEADING TO THE DEGREE OF MECHANICAL ENGINEER

All the subjects leading to the degree of Mechanical Engineer are listed in the following table, together with the year and term in which they are given. The first two years are devoted to essential preparatory and fundamental subjects, mathematics, chemistry, physics, analytical mechanics and drawing, which are co-ordinatedwith kinematics, elementary design, shop work and the elements of electrical and steam engineering. In the third year there are developed the basic principles of thermodynamics, resistance of materials and hydraulics, which are fixed in the mind of the student by drill in the drafting room by design courses, in the laboratory by experiments and tests and in class by analysis of standard mechanical and electrical machinery. The fourth year is devoted to a detailed treatment of gas and steam engine design, standard water turbine characteristics and the essential relations between units constituting power plants and factories. Special attention is here paid to the economics of mechanical engineering by courses in industrial law, economics and works manakement. Throughout the course the aim is to develop clear conceptions of underlying principles, habits of independent thought and orderly mental procedure applicable to any sort of Mechanical Engineering problems rather than to the memorization of isolated facts.

FIRST YEAR

See page 24

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
76	Chemistry 81	Industrial Chemistry	3	
86	Drafting 7	Structural Drafting		3
120	Physics 5	Electricity	2	
96	Mathematics 65	Calculus	5	
96	Mech. Eng. 11	Steam Power Machinery	3	
103	Mech. Eng. 59	Empiric Design	2	3
119	Phys. Educ. B	Gymnasium		2
120	Physics 43	Physical Laboratory		6
122	Shopwork 1	Pattern Making		6
		Total..	15	20
Second Half Year				
76	Chemistry 82	Industrial Chemistry	3	
87	Elect. Eng. 2	Elements of Electrical Engineering	2	
96	Mech. Eng. 12	Steam Power Machinery	3	3
99	Mech. Eng. 36	Kinematics		6
120	Mechanics 102	Analytical Mechanics	5	
110	Metallurgy 134	Iron and Steel	2	
119	Phys. Educ. B	Gymnasium		2
123	Shopwork 2	Moulding and Foundry Practice		3
123	Shopwork 12	Forging		6
		Total..	15	20

SUMMER WORK: Shop Work 10s. 125 hours in College shops; Mech. Eng. 94s. 6 weeks practical work in shops and drafting rooms of manufacturing establishments, with report. A total of 9 weeks.

THIRD YEAR

See Page			Hours per week: Class	Hours per week: Lab'y
		First Half Year		
80	Civil Eng. 53	Resistance of Materials	5	3
88	Elect. Eng. 73	Direct Current Laboratory		3
89	Elect. Eng. 101	Dynamo and Motor Practice	2	
91	Mech. Eng. 17	Technical Thermodynamics	2	
99	Mech. Eng. 31	Mechanical Laboratory	1	3
100	Mech. Eng. 39	Machine Design	1	6
121	Mechanics 105	Thermodynamics	2	
123	Shopwork 11	Machine Work		6
		Total..	13	21
		Second Half Year		
80	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
83	Civil Eng. 78	Hydraulics	2	
88	Elect. Eng. 4	Electric Distribution	2	
96	Mech. Eng. 18	Technical Thermodynamics	2	
99	Mech. Eng. 32	Mechanical Laboratory	1	3
100	Mech. Eng. 40	Machine Design	2	6
102	Mech. Eng. 54	Principles of Machine Manufacture	2	
104	Mech. Eng. 62, Refrig.	Standard machinery for pumping, compressing, elevating and conveying, heating and cooling	6	
104	Mech. Eng. 64, Air Mach.			
104	Mech. Eng. 66, El. & Conv.			
105	Mech. Eng. 70, Pumping			
103	Mech. Eng. 60	Hydraulic Laboratory	1	3
111	Metallurgy 156	Metallographic Laboratory		
		Total..	18	15

SUMMER WORK: Mech. Eng. 96s. 6 weeks practical work in power plant, with report.

FOURTH YEAR

		First Half Year		
88	Elect. Eng. 75	Alternating Current Laboratory		3
89	Elect. Eng. 103	Electric Power	2	
90	Elect. Eng. 105	Electrical Distribution	2	
97	Mech. Eng. 19	Engine Design	3	6
98	Mech. Eng. 25	Power Plant Design	3	6
99	Mech. Eng. 33	Mechanical Laboratory	2	3
101	Mech. Eng. 53	Steam Turbines	2	
104	Mech. Eng. 61	Seminar	1	
		Total..	15	18
		Second Half Year		
95	Law 2	Business Law	3	
86	Economics 2	Economics	3	
97	Mech. Eng. 20	Engine Design	3	6
97	Mech. Eng. 22	Gas Power Machinery	4	3
101	Mech. Eng. 46	Water Power Machinery	3	
101	Mech. Eng. 52	Works Management	2	
104	Mech. Eng. 68	Manufacturing Plant Design	2	3
		Total..	20	12

CHEMISTRY

General Statement

The regular four-year courses of instruction herein shown are designed for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges and scientific schools, or as chemists or managers in manufacturing and other industrial enterprises.

There are two courses offered, leading to the degrees of Chemist and Chemical Engineer respectively.

Equipment

In Havemeyer Hall the Chemical Department is provided with ample space for its museum, lecture-rooms, and laboratories, and every convenience has been provided for both the instructors and students working in the general or special courses.

There are five chemical lecture-rooms, all fully supplied with apparatus and instruments, the desks being equipped with pneumatic troughs, gas, pressure, exhaust, and electricity. The large chemical lecture-room on the ground floor contains 315 seats.

The Chandler Museum of General Inorganic and Organic Chemistry and of the Chemical Arts, a large room occupying the whole left wing of the ground floor, contains the elements and all their more important compounds, inorganic and organic; materials and products illustrating the chemical arts, and numerous models, pictures, and diagrams.

The Qualitative Laboratory has 112 desks, each divided into two sections, and each thoroughly equipped.

The Quantitative Laboratory has eighty-eight desks. Attached to the main laboratory is a large, well-equipped balance-room, containing accurate balances, and special rooms, provided with apparatus for gas, water, food, and electrolytic analysis.

The Assay Laboratory is provided with crucible and muffle furnaces, coal gas and gasoline, for the fire assay of ores; also with crushing, pulverizing, and sampling machinery, balance-room, storeroom, and thirty-six well-equipped working desks. It also contains all the apparatus necessary for the wet assay of silver bullion and for laboratory tests of ores.

The Organic Laboratory has forty large desks, provided with gas, water, exhaust, and electricity, and has special rooms for balances, pressure ovens, glass-blowing, and combustions.

The Laboratory of Industrial Chemistry, for the instruction of

students in practical operations and the solution of problems in connection with the chemical industries, is equipped for the manufacture of pure chemicals from their raw materials on an industrial scale, with fine batteries of steam evaporators, and with steam stills, centrifugals, filter presses, crushers, and the like. It includes a dyeing laboratory with a large stock of dye-stuffs, and with the regular equipment for the practical testing of dyes, including a calico-printing machine. Connected with it is a photometer-room, containing a new and complete outfit for the practical testing of illuminants.

It also includes a laboratory for chemical microscopy, newly equipped with microscopes, polarized light apparatus, camera lucidas, etc., for the practical use of the microscope in chemical operations.

A new Laboratory for Applied Electrochemistry has been provided. The equipment consists of special motor-dynamos, one of which furnishes direct current at low voltages to the students' desks for general electrolytic work; the other provides heavy alternating current to the electric furnace room; this room is furnished with all appliances for electric furnace work. The students' desks are fitted with special switchboards and measuring instruments, and the laboratory has been arranged for carrying on research work in all branches of electrochemistry.

The Laboratory of Physical Chemistry is well equipped with the most recent apparatus adapted to a wide range of experimental work in the branches of heat, light, and electricity as applied to chemical problems.

The Chemical Library in Havemeyer Hall is supplied with an extensive collection of chemical books and journals, and is open from 9.00 A.M. to 5.00 P.M., and during the session of the University from 8.00 to 11.00 P.M.

COURSE LEADING TO THE DEGREE OF CHEMICAL ENGINEER

The regular four-year course of instruction shown below is designed primarily for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges after pursuing further studies, or as research chemists, chemists or managers in manufacturing and other industrial enterprises.

The course in chemical engineering, as will be seen, is designed to educate chemists with a sufficient amount of engineering to fit them to take charge of chemical works which depend largely on the use of machinery. This requires a knowledge of mechanical engineering, electrical engineering, hydraulics, mechanical drawing, shopwork, etc., as well as a thorough knowledge of chemistry in all its branches. Such an education qualifies a man to act as manager of gas works, sugar refineries, dyeing and calico-printing establishments, electro-chemical works, etc.

FIRST YEAR

See page 24

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Organic Chemistry	2	
76	Chemistry 81	Industrial Chemistry	3	
74	Chemistry 163	Quantitative Analysis	4	9
86	Drafting 7	Structural Drafting		6
120	Physics 5	Electricity	2	
96	Mathematics 65	Differential Integral Calculus	5	
114	Mineralogy 15	Determinative Mineralogy		3
119	Phys. Educ. B	Gymnasium		2
		Total..	16	20
Second Half Year				
72	Chemistry 42	Organic Chemistry	2	
76	Chemistry 82	Industrial Chemistry	3	
74	Chemistry 164	Quantitative Analysis	4	15
87	Elect. Eng. 2	Elements of the Dynamo	2	
120	Mechanics 102	Analytical Mechanics	5	
114	Mineralogy 16	Determinative Mineralogy		3
119	Phys. Educ. B	Gymnasium		2
		Total..	16	20

SUMMER WORK: Chemistry 80a, Chemistry s69. Shopwork 18s (8), 3 weeks in June.

THIRD YEAR

See Page		First Half Year	Hours per week Class	Lab'y
80	Civil Eng. 53	Resistance of Materials	5	3
76	Chemistry 83	Industrial Chemistry	3	
74	Chemistry 171	Organic and Sanitary Analysis	4	9
96	Mech. Eng. 13	Steam Power Machinery	3	
103	Mech. Eng. 59	Empiric Design	2	3
109	Metallurgy 131	Iron and Steel (half term)	1	
110	Metallurgy 141	Electro-metallurgy (half term)	1	
		Total..	19	15
		Second Half Year		
81	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
76	Chemistry 84	Industrial Chemistry	3	
73	Chemistry 150	Organic Chemistry	2	9
88	Elect. Eng. 72	Direct Current Laboratory		3
88	Elect. Eng. 4	Electric Distribution	2	
96	Mech. Eng. 14	Steam Power Machinery	3	
105	Mech. Eng. 70	Pumps and Pumping Machinery	2	
		Total..	12	15

SUMMER WORK: Chemistry 80b. Chemical Factory work with Memoir—6 weeks.

FOURTH YEAR

		First Half Year	Hours per week	
83	Civil Eng. 77	Hydraulics	2	
76	Chemistry 85	Industrial Chemistry	3	
77	Chemistry 89	Industrial Laboratory		3
77	Chemistry 97	Factory Location and Construction	3	
71	Chemistry 121	Physical Chemistry	3	2
96	Mech. Eng. 17	Technical Thermodynamics	2	
100	Mech. Eng. 39	Machine Design	1	6
106	Mech. Eng. 77	Experimental Engineering Laboratory	1	3
108	Metallurgy 101, 111	Introduction and Metallurgy of Copper	3	
		Total..	18	14
		Second Half Year		
76	Chemistry 86	Industrial Chemistry	3	
77	Chemistry 98	Factory Apparatus and Machinery	1	
71	Chemistry 122	Physical Chemistry	3	
78	Chemistry 184	Practical Electro-Chemistry	2	3
	Chemistry	Thesis		9
96	Mech. Eng. 18	Technical Thermodynamics	2	
101	Mech. Eng. 52	Works Management	2	
106	Mech. Eng. 76	Experimental Engineering Laboratory	1	3
112	Metallurgy 72	Laboratory		2
109	Metallurgy 122	Metallurgy of Gold, Silver, Lead, Zinc	3	
		Total..	17	17

COURSE LEADING TO THE DEGREE OF CHEMIST

The regular four year course of instruction shown below is designed for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges and scientific schools, after further preparation, or as chemists or research chemists in manufacturing and other industrial enterprises.

The course in chemistry includes not only all branches of theoretical, analytical, and industrial chemistry, but also collateral sciences, such as mathematics, mechanics, physics, mineralogy, metallurgy, mechanical and electrical engineering, and drawing, which have been found by experience to be required by the professional chemist. It is the intention to provide the graduate not only with a thorough knowledge of the principles and practice of chemistry in all its branches, but with such a broad and liberal education in the collateral sciences as will prepare him for every demand that will be likely to be made upon him in connection with his profession or in the pursuit of investigation.

FIRST YEAR

See page 24

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
71	Chemistry 21	Elementary Physical Chemistry	2	
72	Chemistry 41	Elementary Organic—Lecture Course	2	
76	Chemistry 81	Industrial Chemistry—General Course	3	
74	Chemistry 163	Quantitative Analysis	4	12
120	Physics 5	Elements of Electrical Engineering	2	
96	Mathematics 65	Differential and Integral Calculus	5	
114	Mineralogy 15	Determinative Mineralogy		3
119	Phys. Educ. B	Gymnasium		2
		Total..	18	17
Second Half Year				
71	Chemistry 22	Elementary Physical Chemistry	3	2
72	Chemistry 42	Elementary Organic—Lecture Course	2	
76	Chemistry 82	Industrial Chemistry—General Course	3	
74	Chemistry 164	Quantitative Analysis	4	12
87	Elect. Eng. 2	Elements of Dynamo	2	
120	Mechanics 102	Analytical Mechanics	5	
114	Mineralogy 16	Determinative Mineralogy		3
119	Phys. Educ. B	Gymnasium		2
		Total..	19	19

SUMMER WORK: Chemistry 80a—Memoir.

THIRD YEAR

See Page		First Half Year	Hours per week Class	Lab'y
76	Chemistry 83	Industrial Chemistry	3	
77	Chemistry 91	Chemical Microscopy		4
71	Chemistry 101	Advanced Inorganic	2	
74	Chemistry 171	Organic and Sanitary Analysis	4	15
78	Chemistry 183	Industrial Electrochemistry	1	
96	Mech. Eng. 13	Steam Power Machinery	3	
109	Metallurgy 131	Iron and Steel (half term)	1	
110	Metallurgy 141	Electro-metallurgy half-term	1	
		Total..	15	19
		Second Half Year		
76	Chemistry 84	Industrial Chemistry	3	
77	Chemistry 88	Industrial—Laboratory Course		6
77	Chemistry 92	Chemical Microscopy		4
71	Chemistry 102	Advanced Inorganic Chemistry	2	
75	Chemistry 170	Assaying	2	9
78	Chemistry 184	Industrial Electrochemistry	1	3
96	Mech. Eng. 14	Steam Power Machinery	3	
		Total..	11	22

SUMMER WORK: Chemistry 80b—Memoir.

FOURTH YEAR

		First Half Year			
71	Chemistry 7	Inorganic Chemistry—or	Elective or taken from afternoons	(2)	
72	Chemistry 23	Physical Chemistry—or			
78	Chemistry 93	Electro Chemistry—or			
78	Chemistry 95	Industrial Chemistry—or			
73	Chemistry 143	Organic Chemistry—or			
74	Chemistry 167	Adv. Inorg. Anal. Chem.—or			
75	Chemistry 173	Adv. Org. Anal. Chemistry			
76	Chemistry 85	Industrial Chemistry		3	
77	Chemistry 89	Industrial Chemistry—Lab. Practice			3
71	Chemistry 121	Physical Chemistry		3	2
72	Chemistry 141	Organic Chemistry—General Course		5	12
108	Metallurgy 101, 111	Introduction and Metal'gy of Copper		3	
109	Metallurgy 131	Iron and Steel (half term)*		1	
		Total..		15	17

* For 1910—11 only.

		Second Half Year		
76	Chemistry 86	Industrial Chemistry	3	
71	Chemistry 122	Physical Chemistry	3	
72	Chemistry 142	Organic Chemistry—General Course	5	
109	Metallurgy 122	Lead, Silver, Gold and Zinc	3	
	Thesis—		2	15
71	Chemistry 8	Inorg. Chemistry—or		
72	Chemistry 24	Physical Chemistry—or		
78	Chemistry 94	Electro-Chemistry—or		
77	Chemistry 96	Industrial Chemistry—or		
73	Chemistry 144	Organic Chemistry—or		
74	Chemistry 168	Adv. Inorg. Anal. Chemistry—or		
75	Chemistry 174	Adv. Org. Anal. Chemistry—or		
75	Chemistry 176	Food Chemistry		
		Total..	16	15

COURSES OF INSTRUCTION

Arranged Alphabetically by Departments

ASTRONOMY

105—Geodesy. 3 hours. Professor S. A. MITCHELL.

Brief history of geodetic operations and description of theodolites, base apparatus, and other instruments used in geodetic work, including their adjustment and use. Text-book: Wilson's *Topographic Surveying.*

106—Geodesy. 1 hour and 1 laboratory period. Professor S. A. MITCHELL.

The applications of practical astronomy to geodetic surveying, and training in methods of accurate computation. Text-book: Wilson's *Topographic Surveying.*

107—Geodesy. Professors JACOBY and S. A. MITCHELL, with Assistants.

Summer Course in Practical Geodesy: Given at Camp Columbia, Morris, Conn.

Pre-requisite for all courses: Mathematics of first two years.

BACTERIOLOGY

101—Sanitary Bacteriology. 2 hours and 2 afternoons a week for nine weeks. Professor HISS and Assistants.

Practical instruction in Bacteriology and Hygiene. A short course for Sanitary Engineering Students, adapted from and covering the more important topics treated in Courses 51 and 201. The course opens with the study of the relationship of bacteria to other micro-organisms. It embraces the methods of staining, examining, and cultivating. The student is taught by practical exercises the methods of separating one species of bacteria from another, and the series of biological characters used in identification of the various forms. The general and special relationship of micro-organisms to disease is considered. Finally some of the hygienic aspects of bacteriology are studied by experiments in the sterilization of infectious material, disinfection of the hands, and by practice in the biology of air, water, milk, and other foods, and soil analysis. For students in Sanitary Engineering.

Pre-requisite: Chemistry 65, 92*a*.

BOTANY

7—Growth and Character of Timber. Professor CURTIS and Dr. DARLING.

This work considers the growth of the tree and the character and arrangement of its tissues; the relation of moisture to the strength

of timber; the deterioration and preservation of lumber and its distribution and identification.

One hour and one afternoon each week during first term of second year for Civil Engineering students.

CHEMISTRY

Courses

The following courses in Chemistry are included in the programs of study of the Schools of Mines, Engineering and Chemistry. For other courses offered see the *Announcement of the Division of Chemistry.*

Inorganic Chemistry

3-4—General Inorganic Chemistry. 3 lectures and 1 recitation. Professor WHITAKER and Dr. KRESS.

Introduction. Laws of chemical combination, history, occurrence, preparation, and properties of the elements and their principal compounds.

Pre-requisite: Course Chem. A or Entrance Examination in Chemistry.

7-8—Inorganic Chemistry. 2 hours lectures or conferences throughout the year and 5 afternoons laboratory during the second half-year. Professor WHITAKER.

Designed for fourth-year students in the course of chemistry selecting a thesis in inorganic chemistry.

101-102—Advanced Inorganic Chemistry. 2 lectures. Professor WHITAKER.

Including the origin and development of the periodic law, and the history and properties of the rare elements.

Pre-requisite: Courses 3-4 and 61-62.

Summer Courses

For details, see the *Announcement of the Summer Session.*

S1 (S6)—General Chemistry. 5 hours lectures, 12 hours laboratory work, and 2 hours recitations. Mr. WILLIAMS and Mr. WHITMAN.

Physical Chemistry

21-22—Elementary Physical Chemistry. 2 hours lectures and recitations first half-year and 3 hours second half-year, with laboratory work 15 afternoons second half-year (equivalent to 1 afternoon throughout the half-year). Professor MORGAN and Assistant.

Text-books: Portions of Morgan's *Physical Chemistry for Electrical Engineers* and Ostwald's *Physico-Chemical Measurements.*

Pre-requisite: Course 3-4 and Physics 3-4.

121-122—Physical Chemistry. 3 hours lectures and recitations during the entire year, and 15 afternoons, equivalent to 1 afternoon a week, laboratory during the first half-year. Professor MORGAN and Assistant.

A course treating of the states of aggregation, solution, and ions in analytical chemistry, thermo-chemistry, chemical mechanics, and electro-chemistry. Text-books: Morgan's *Elements of Physical Chemistry,* and Ostwald's *Physico-chemical Measurements.*

Pre-requisite: Course 3-4 and 61-62, Physics 3-4 and Mathematics 5-6.

38—**Theoretical Electro-chemistry.** 2 hours lectures and recitations. Professor MORGAN.

Text-book: Portions of *Morgan's Physical Chemistry for Electrical Engineers.*

Pre-requisite: Course 3-4 and 65, Physics 3-4, and Mathematics 5-6.

23-24—**Physical Chemistry.** 2 hours in lectures or conferences throughout the year, and 5 afternoons laboratory during the second half-year. Professor MORGAN.

Designed for four-year students in the course of chemistry, selecting a thesis in physical chemistry.

Summer Courses

For details, see the *Announcement of the Summer Session.*

S138—**Elementary Physical Chemistry.** 5 hours. Professor MORGAN.

Research. The laboratory is open to properly qualified students for research under the direction of Professor MORGAN.

Organic Chemistry

41-42—**Organic Chemistry, Elementary Lecture Course.** 2 hours. Dr. NELSON.

An introductory course, which can be taken with advantage by college students and by those expecting to enter the medical course. Instruction given on such important classes of compounds as the hydrocarbons, alcohols, ethers, organic acids, fats, waxes, soaps, cyanides, sugars, carbohydrates, alkaloids, coloring matters, drugs, perfumes, and the like. The lectures will be liberally illustrated by material from the Chemical Museum and by experimental demonstration. Text-book: Perkin & Kipping's *Organic Chemistry.*

Pre-requisite: Course 3-4. It is urged that, if possible, laboratory work, Course 43-44, be taken with this elementary lecture course.

43-44—**Organic Chemistry, Elementary Laboratory Course.** 8 hours. Dr. NELSON and Assistant.

A study of the typical methods for preparation and the typical reactions of the important classes of organic compounds. The laboratory work may be varied according to the needs of the student. Text-book: Gattermann's *Practical Methods of Organic Chemistry.*

Pre-requisite or parallel: Courses 3-4 and 41-42.

141-142—**Organic Chemistry, General Course.** 4 lectures and 1 recitation a week for one year, and 4 afternoons laboratory the first half-year. Professor BOGERT, Dr. NELSON and Assistant.

A more comprehensive treatment of the subject, including a discussion of all the important classes of organic compounds. In the

laboratory a large number of typical organic substances are prepared synthetically, and instruction is given in the methods of qualitative and ultimate organic analysis. In addition to this, students taking the course as a major for A.M. are required to submit an essay upon some special line of practical work assigned by the instructor. Text-books: Holleman's *Organic Chemistry,* Gattermann's *Practical Methods of Organic Chemistry.*

Pre-requisite: Courses 3-4, 21-22, and 161-162.

143-144—Organic Chemistry, Conferences. 2 hours. Professor Bogert.

Presentation and discussion of recent important investigations in the field of organic chemistry.

Required, together with 5 afternoons laboratory practice the second half-year, of all fourth-year students in the School of Chemistry selecting a thesis in organic chemistry. Pre-requisite or parallel: Course 141-142.

150—Advanced Organic Chemistry for Chemical Engineering Students. 2 lectures and 3 afternoons per week, second half-year. Dr. Nelson and Assistant.

The study of organic compounds and reactions with particular reference to their relation to commercial products and manufacturing processes.

Pre-requisite: Course 41-42 or its equivalent. Required of all third-year chemical engineering students.

151-152—Advanced Organic Chemistry, Laboratory Course. 2 afternoons per week. Professor Bogert, Dr. Nelson and Assistant.

The synthesis and study of any one of such important groups of organic compounds as (*a*) dyestuffs, (*b*) essential oils, (*c*) alkaloids, (*d*) synthetic drugs and organic substances of special interest to the medical profession, or similar groups to be selected by conference with the instructor.

For chemical engineers electing a thesis in organic chemistry, 3 afternoons per week, second half-year. Minor for A.M. or Ph.D. or major for A.M., depending upon amount of work performed.

Pre-requisite: Courses 3-4, 41-42, and 43-44.

S43-44 (S30)—Organic Chemistry, Laboratory Course. Dr. Nelson and Assistant.

SF—Chemistry of Nutrition. (See page 76.)

Research. The laboratory is open to properly qualified students for research under the direction of Dr. Nelson and Assistant.

Analytical Chemistry

61 or 62—Qualitative Analysis. 4 hours and 5 afternoons. Dr. Beans, Dr. Zanetti, Mr. Moore, Dr. Uhlig.

Theory and practice of qualitative analysis based upon the principles of physical chemistry. Text-book: Böttger's *Qualitative Analysis.*

Pre-requisite: Course 1 or 2 or its equivalent.

65—Quantitative Analysis, Inorganic, Short Course. 2 hours and 2 afternoons. Dr. Metzger and Dr. Joüet.

Text-books: Miller's *Notes on Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

The analyses included in this course are: Magnesium sulphate, potassium alum, coal, iron ore, copper, zinc, alkalimetry, acidimetry, and flue gas.

Pre-requisite: Courses 3-4 and 61 or 62.

66—**Quantitative Analysis, Inorganic.** 3 hours and 5 afternoons. Dr. METZGER, Dr. JOÜET and Assistants.

Text-books: Miller's *Notes on Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

The analyses included in this course are: Magnesium sulphate, potassium alum, iron-ammonium alum, coal, iron ore, pig iron, spiegel, zinc ore, limestone, slag, copper, lead, arsenic, antimony ores, and flue gas.

Pre-requisite: Courses 3-4 and 61 or 62.

71—**Quantitative Analysis.** 2 lectures and 6 hours laboratory, counting as 5 points. Dr. METZGER and Dr. JOÜET.

Pre-requisite course: M. E. 67-68.

161-162—**Quantitative Analysis, Inorganic.** 1 hour and 8 hours laboratory. Dr. METZGER and Assistant.

Text-book: Talbot's *Quantitative Analysis.*

Pre-requisite: Courses 3-4 and 61 or 62.

163-164—**Quantitative Analysis.** 4 hours and 4 afternoons. Dr. METZGER and Dr. JOÜET.

The classroom work includes not only the methods applied in the laboratory, but discussions of quantitative separations from a theoretical standpoint, and chemical calculations. Text-books: Treadwell's *Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

The analyses included in this course are: Magnesium sulphate, sodium or other chloride, potassium alum, iron ammonium alum, coal, iron ore, pig iron, spiegel, limestone, slag, feldspar, ores of zinc, copper, nickel, lead, chromium, arsenic, antimony, alloys, rocks, gas analysis, etc.

Pre-requisite: Courses 3-4 and 61 or 62.

167-168—**Advanced Inorganic Analysis.** 2 hours. Dr. METZGER.

Laboratory practice 5 afternoons during the second half-year for students in the course of Chemistry, who elect thesis work in inorganic analytical chemistry.

In the first half-year, systematic volumetric analysis and technical analytical methods connected with iron, steel, copper, lead and zinc metallurgy. In the second half-year, rock analysis and the analytical chemistry of the rare elements.

Pre-requisite or parallel: Chemistry 101-102, 121-122, 163-164.

171—**Organic and Sanitary Analysis.** 4 hours and laboratory work 5 afternoons for chemists, 3 afternoons for chemical engineers, 3 to 5 afternoons for graduate students. Professor SHERMAN and Assistant.

The lectures include general and industrial organic analysis, food and fertilizer analysis and inspection, examination of drinking water. Special attention is given to the interpretation of the analytical results. Text-books: Sherman's *Methods of Organic Analysis* and Mason's *Examination of Water;* for reference, Richards and Woodman's *Air, Water and Food.*

The analyses included in this course are: Acidimetry and alkalimetry, alcohol, glycerol, formaldehyde, sugars, cream of tartar, milk, butter, fatty and lubricating oils, soap, paint, asphalt, fertilizers, and the sanitary analysis of water.

Pre-requisite: Courses 3-4, 61-62, 161-162 and 41-42.

173-174—**Advanced Organic Analysis.** 2 hours throughout the year and laboratory work during the second half-year, 5 afternoons for fourth-year students in the Chemistry course who elect thesis work in organic analytical chemistry or food chemistry. Professor SHERMAN.

The analytical chemistry of proteins and their derivatives, alkaloids, tannins and fibres; plant analysis; advanced methods in food analysis; measurement of the activity of enzymes and the digestibility and nutritive value of food; systematic review of organic analysis.

Pre-requisite or parallel: Course 171 (or equivalent work in 271-272).

176—**Chemistry of Food and Nutrition.** 3 hours. Professor SHERMAN.

The chemistry and functions of the foodstuffs; the composition and nutritive values of food materials; the amounts of food required in nutrition; methods of determining the nutritive values of special foods and the effects of adulteration; food legislation and inspection; standards of purity for food products; normal and abnormal variations in composition.

69 or 170—**Assaying.** 2 lectures or recitations a week, and laboratory practice, during the first half-year for mining engineers and metallurgists; during the second half-year for chemists. Mr. HALL.

Ores and metallurgical products. Text-book: Fulton's *Manual of Assaying.*

The assays included in this course are: Preliminary (reagents, etc.); lead ores; gold and silver ores, pure and impure, including galena, stibnite, arsenopyrite, blende, pyrite, tellurides, etc.; mattes and tailings; corrected assays and extraction tests; gold, silver, and lead bullions.

Laboratory work for mining engineers and metallurgists, 3 afternoons during the first half-year; for chemists, 3 afternoons during the second half-year.
Pre-requisite: Courses 3-4, 61-62, and Mineralogy 1-2 or 7-8.

160—**Special Methods of Assaying Ores, Alloys, and Furnace Products.** Conferences and laboratory work at least 8 hours a week for one half-year. Mr. HALL.

Comparison of methods and determination of losses.

Pre-requisite: Courses 3-4, 61-62, 69, and Mineralogy 1-2 or 7-8.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s61-62—**Qualitative Analysis.** 10 hours lectures and conferences, and 30 hours laboratory work a week. Dr. BEANS.

s69 or 170—**Assaying.** 5 hours lectures and 30 hours laboratory work a week. Mr. HALL.

Required of Chem. Engineers.

s161-162—**Quantitative Analysis.** 5 hours lectures and 30 hours laboratory work a week (accepted for Course 65). Dr. JOÜET.

sF—Chemistry of Nutrition. 5 hours lectures. Professor SHERMAN.

s171a—Organic and Sanitary Analysis. Conferences and laboratory work 12 to 30 hours a week. Professor SHERMAN and Assistant.

s171b*—Food Analysis and Inspection. Professor SHERMAN.

s171c*—Industrial Organic Analysis. Professor SHERMAN.

*Given alternate years.

Research. The laboratory is open to properly qualified students for research, in organic analytical chemistry or the chemistry of foods, under the direction of Professor SHERMAN.

Industrial Chemistry

81-82—Industrial Chemistry, General Course. 3 hours lectures. Professor WHITAKER and Dr. KRESS.

The subjects discussed are: (1) Air: nature, sources of contamination, sewer gas, plumbing, draining, disinfection, ventilation. (2) Water: composition of natural waters, pollution, disposal of sewage and house refuse. (3) Artificial illumination: candles, oils and lamps, petroleum, gas and its products, electric light. (4) Limes, mortars, and cements. (5) Building-stones: decay and preservation. (6) Timber and its preservation: pigments, paints, essential oils, varnishes, preserving processes. (7) Explosives: gunpowder, gun-cotton, nitro-glycerine. (8) Glass and ceramics. (9) Electro-metallurgy. (10) Photography. Text-books: Park's *Hygiene* and Wagner's *Chemical Technology.*

Pre-requisite: Course 3-4.

83-84—Industrial Chemistry, Special Course. 3 lectures. Professor WHITAKER and Dr. KRESS.

The subjects discussed are: (1) Chemical manufactures: acids, alkalies, and salts. (*a*) Sulphur, sulphurous acid, hyposulphites, sulphuric acid, bisulphide of carbon. (*b*) Common salt, soda ash, hydrochloric acid, chlorine, binoxide of manganese, bleaching powder, chlorates, chlorimetry. (*c*) Carbonate of potash, caustic potash. (*d*) Nitric acid and nitrates. (*e*) Iodine, bromine. (*f*) Sodium, aluminum, magnesium. (*g*) Phosphorus, matches. (*h*) Ammonia salts. (*i*) Cyanides. (*j*) Alum, copperas, blue vitriol, salts of magnesia, baryta, strontia. (*k*) Borates, stannates, tungstates, chromates. (*l*) Salts of mercury and silver. (*m*) Oils, fats, soaps, and glycerine. Text-books: Thorpe's *Outlines Industrial Chemistry;* Wagner's *Chemical Technology;* Lunge's *Manufacture of Sulphuric Acid and Soda.* Given alternate years.

Pre-requisite: Courses 3-4, 81-82.

85-86—Industrial Chemistry, Special Course (continued). 3 hours lectures. Professors WHITAKER, SHERMAN and Dr. KRESS.

(2) Food and drink: milk, cereals, starch, bread, meat, tea, coffee, sugar, fermentation, wine, beer, spirits, vinegar, preservation of food. (3) Clothing: textile fabrics, bleaching, dyeing, calico printing; paper, tanning, glue, india-rubber, gutta-percha. (4) Fertilizers: guano, superphosphates, poudrettes. Text-books: Sadtler's *Industrial Organic Chemistry;* Wiley's *Foods and Their Adulteration;* Wagner's *Chem-*

ical Technology; Schultz' and Julius' *Kuenstlichen Organischen Farbstoffe;* Schultz' *Chemie des Steinkohlentheers.* Given alternate years.

Pre-requisite: Courses 3-4, 81-82.

88—Industrial Chemistry, Laboratory Practice. 3 afternoons. Professor WHITAKER and Dr. KRESS.

Preparation of inorganic chemicals, including the preparation and purification of chemical reagents, pigments, and salts of the rare as well as of the common metals.

Pre-requisite: Courses 3-4, 61-62.

89—Industrial Chemistry, Laboratory Practice. 1 afternoon a week. Professor WHITAKER and Dr. KRESS.

Special applications: Textile industry, vegetable and animal fibres, bleaching, dyeing, and calico printing.

Pre-requisite: Course 3-4, 61-62, 147-148.

91-92—Chemical Microscopy. 4 hours lectures and laboratory practice a week. Professor WHITAKER and Dr. KRESS.

The use of the microscope for the identification of crystalline chemical compounds, fibres, starches, urinary sediments, micro-organisms, etc., with special application to the detection of poisons and food adulterants.

92a—Microscopy. Laboratory and conference, 2 hours a week during February and March. Professor WHITAKER and Dr. KRESS.

Construction, use, and care of the microscope. Examination and identification of common fibres, starches, spices, yeasts and other objects of economic importance. Common adulterants. Measurement of sand grains, micro-organisms, etc.

Pre-requisite: Chemistry 65.

95-96—Industrial Chemistry. 2 hours throughout the year, and 5 afternoons in the laboratory during the second half-year. Professor WHITAKER and Dr. KRESS.

Designed for fourth-year students in the course of chemistry selecting a thesis in industrial chemistry.

97—Chemical Factory Location and Construction. 3 hours. Professor WHITAKER and Dr. KRESS.

To cover different problems connected with the location, construction and equipment of chemical factories.

98—Chemical Factory Apparatus and Machines. 1 hour. Professor WHITAKER and Dr. KRESS.

To cover the construction and use of the apparatus and machinery used in chemical factories.

80a—Factory Inspection and Summer Memoir. Professor WHITAKER and Dr. KRESS.

Visiting and inspection of chemical works of special interest in and near New York City, such as gas works, petroleum refineries, sugar houses, dyeing and calico-printing establishments, paint and varnish factories, soap, candle and oleomargarine works, paper mills, and plants for the purification of water and sewage.

Also a memoir descriptive of some chemical process, the subject to be assigned to each student.

Required of all second-year students in the courses of chemistry and chemical engineering. The visits to factories are made during the two weeks following the final examinations. The memoir must be wholly completed by December 1st.

80b—Factory Inspection and Summer Memoir. Professor WHITAKER and Dr. KRESS.

Similar to 80a, excepting that the memoir covers description, working plans, and full estimate of cost of a chemical laboratory, according to outlines assigned to each student.

Required of all third-year students in the course of chemistry.

Required, without memoir, of all third-year students in the course of chemical engineering.

Electro-Chemistry

93-94—Electro-Chemistry. 2 hours in lectures or conferences throughout the year, and 5 afternoons in the laboratory during the second half-year. Professor TUCKER.

Designed for fourth-year students in the course of chemistry or chemical engineering selecting a thesis in electro-chemistry.

181 or 182—Practical Electro-Chemistry. 10 hours per week. Professor TUCKER.

Electro-plating, influential factors in electrolysis, electrolysis with molten electrolytes, the use of diaphragms, electrolytic preparations, electric furnace practice.

Pre-requisite: Courses 3-4, 61-62, 65.

183-184—Industrial Electro-Chemistry. 1 hour and the equivalent of 14 afternoons laboratory work. Professor TUCKER.

Theory and practice of electrolysis or electro-deposition, electric smelting and refining, primary and secondary batteries, production, preparation and purification of chemicals and metals.

Pre-requisite: 3-4, 65.

CIVIL ENGINEERING

2—Theory of Surveying. Lectures and recitations, 2 hours, second half-year. Professor LOVELL, Mr. FOOTE and Assistants.

For first-year students in the Schools of Mines, Engineering, and Chemistry.

Methods of measuring angles and distances. Cumulative and compensating errors, and corrections to be applied. Limits of precision. Use, care, and adjustment of the engineer's transit, level, and compass. Magnetic declination and variation. Local attraction. Relocation of old lines by compass bearings. Erroneous standards. Surplus and deficiency. Significance of monuments. Traverses; computations of area and error of closure. Laying out and dividing up land. System of public land surveys. Topographic surveys; transit stadia and plane table methods. Triangulation. City surveying, subdivision and re-surveys. Interpretation of deed descriptions. Text-book: Tracy's *Plane Surveying*.

15—Surveying between the First and Second Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FOOTE, and Assistants.

Survey 1 includes pacing and chaining, ranging out lines, contouring with hand level, mapping. *Survey 2* consists of the adjustment of the level and in running a line of differential levels. Note book and report. *Survey 3* consists of the adjustment of the transit, angle reading by repetition, determination of stadia constant, and running an azimuth traverse in which horizontal distances are determined by the stadia, and differences of elevation computed from the vertical angle. Note book and map. *Survey 4* consists of a compass survey of a closed field, location of boundaries and principal details, computation of area, and map. *Survey 5* consists of repetition traverse of a closed field, distances being measured by steel tape corrected for catenary, pull, and temperature. Determination of magnetic declination by observation on Polaris.

Pre-requisite: 2.

21—Highway Engineering. Lectures and recitations, 2 hours. Dr. ———.

Road resistances—Design, construction, maintenance and repair, of Dirt, Gravel, Broken Stone and Miscellaneous Roads—Street Location—City pavements—Belgian and Granite Block, Brick. Asphalt and Wooden Block—Foundations—Grades—Drainage, Specifications. Reference and text-books: Morrison's *Highway Engineering.*

23—Theory of Railroad Surveying. 2 hours and 1 afternoon problem work. Professor LOVELL and Mr. FOOTE.

An abridged course, for students in Mining Engineering, covering the same subjects as are taken in Course 51-52.

Pre-requisite: 15.

25—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FOOTE and Assistants.

Survey 1 consists of running a line of levels for a water main or sewer, plotting profile, and computation of excavation. *Survey 2* consists of a topographic survey with plane table. Intersection, re-section, and traverse methods to be used, and map made. *Survey 3* consists of a topographic survey with transit and stadia; note-book and map. An optional course in photographic surveying may be offered in 1911. *Survey 4* consists of solar observations with transit and solar compass for the determination of the true meridian and magnetic declination. *Survey 5a,* City surveying, consists of the division of land into city blocks and subdivision into lots and the location of the street and lot lines; grade lines for streets and grades at street intersections; location and grade of sewers; including map, profile, and computation of excavation for street opening and sewer line. Relocation of lot lines and problems in surplus and deficiency, map showing property with record line and encroachments. Location of lines for buildings, bridge abutments, etc.

Pre-requisite: 15.

26—Surveying between the Third and Fourth Years. Hydro-

graphic Survey. Field and office work. 2 weeks. Professor LOVELL, Mr. FOOTE and Assistants.

Survey made in conjunction with Geodetic Survey (total time 5 weeks, see page 70, Dept. of Astronomy), which furnishes main triangulation net for topographic and hydrographic control. Hydrographic survey consists of auxiliary triangulation, topography on shore by stadia, soundings, observations on outlet by current meter for river discharge, adjustment of angles, computation of triangulation system, also of river discharge, map and report.

Pre-requisite: 25.

27—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FOOTE and Assistants.

Same as C. E. 25 except Survey *5a* is omitted and *Survey 5b* is added. *Survey 5b* consists of the location of a mining claim 1,500 feet long by 300 feet wide in conflict with existing claims, and the determination of the areas in conflict. The claim is located upon an outcrop of assumed dip and strike, in such a manner as to keep the center line close to the outcrop. Reports and maps.

Pre-requisite: 15.

28—Surveying between the Second and Third Years. Field work and office work. 3 weeks. Professor LOVELL, Mr. FOOTE and Assistants.

Railroad surveying—Reconnaissance—Prelimary survey—Location—Cross-sectioning—Computation—Economic comparisons from construction and operating standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, calculations of earthworks, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 23, 27.

51-52—Theory of Railroad Surveying. 2 hours and 1 afternoon, first term, and 3 hours and 1 afternoon problem work. Professor LOVELL and Mr. FOOTE.

Simple, compound, and reversed curves—Transition curves—Switch work—Cross-section work—Earthwork computations—Cost of earthwork; cut and fill—Borrow—Waste and overhaul—Office work; Profile with mass curve showing proper distribution of excavation. Lectures and practical problems. Reference books: Searle's *Field Engineering* and Crandall's *Transition Curve and Earthwork.*

Pre-requisite: 15.

53-54—Elasticity and Resistance of the Materials of Engineering. 5 hours lectures and recitations first half. 6 hours first half-year of problem, design and laboratory work; 3 hours second half. Professors BURR and WILLIAMS, Mr. MACGREGOR and Mr. ———

Laws of elasticity in homogeneous materials—Coefficients of elasticity—Relations between stresses and strains—Common and exact theories of torsion and flexure—Elastic limits, working stresses, and ultimate resistances of wrought iron, cast iron, steel, alloys, timbers, building-stones, cement, concrete, and masonry—Reinforced concrete

construction—Complete treatment of simple and continuous beams—The design and construction of iron, steel, and timber columns and beams, including the design and construction of plate girders—Shafts—Cables—Fatigue of materials—Specifications—Testing Laboratory—Discussion of properties of structural materials as shown by results of testing, by tension, compression, bending, and torsion—Report of tests. Reference and text-book: Burr's *Elasticity and Resistance of Materials.*

Pre-requisite: Mechanics 102.

55—Standard Methods of Water Analysis. 2 afternoons. Professor BLACK.

Physical and biological.

Pre-requisite: Zoology 7, Bacteriology 101, Civil Engineering 59.

57a—Statistics and Interpretation of Water Analyses. A course of 20 lectures. Mr. G. C. WHIPPLE.

Collection, preparation and interpretation of vital statistics, for the identification of the sanitary condition of particular States, cities, or communities as affected by water and milk supplies, sewerage systems, industrial and economic conditions. Interpretation of complete water analyses.

57b—Drainage of Marshes and Lowlands. A course of 10 lectures. Professor BLACK.

Mosquitoes, habits, breeding, methods of extermination. Malaria, yellow fever.

Pre-requisites for courses 57*a* and 57*b* are Zoology 7, Bacteriology 101, and Civil Engineering 59.

58—Masonry Structures. Lectures 3 hours with frequent conferences and continuous work in design. Cement and mortar testing in the cement-testing laboratory are required of all students. Professor WILLIAMS.

Pressure and abutting power of earth—Design and construction of retaining walls—Stability of masonry structures in general—Stability of towers and chimneys under wind pressure—Theory and design of arches with vertical and inclined loads—Theory and design of reservoir walls, earth and high masonry dams—Theory and Design of masonry domes—Cement, concrete, and masonry. Reference books: Cain's *Retaining Walls* and Baker's *Masonry and Foundations.*

Pre-requisite: Mechanics 101-102, Mineralogy 5.

59—Sanitary Engineering. 2 hours lectures and 2 afternoons in January in Bacteriological Laboratory. Professor BLACK.

Treatment and disposal of sewage and refuse of manufacturing—Sedimentation by gravity and by chemical precipitation—Treatment of effluent by continuous and intermittent sand filtration—Septic tanks—Contact beds—Percolating or trickling filters—Fertilization—Intermittent application to soil with under-drainage—Disposal of sludge—Plants for sewage treatment—Theory and construction of sand filters—Pollution of potable water and its purification by continuous and intermittent sand filtration—Mechanical filtration—Copper sulphate, ozone and other treatments for special waters—Design of sand filter for water purification. Examinations of and reports on typical purifica-

tion works. Biology and Bacteriology of drinking water. Text-books: *Filtration of Public Water Supplies,* Hazen; *Purification of Sewage,* Barwise.

Pre-requisite: Chemistry **82.**

61—Analytical Theory of Trusses. 2 hours lectures, with frequent conferences and problems in computations of stresses and preparation of stress sheets. 1 afternoon of problem and design work in the drawing academy. Professor WILLIAMS.

The truss element—Simple cantilever and non-continuous trusses with parallel chords—Fixed and moving loads—Through and deck spans—Positions of any system of concentrated moving loads for greatest chord and web stresses when chords are both parallel and non-parallel—Combination of moments and graphic methods—Skew and irregular trusses—Applications to bridge and roof trusses—Braced arches and arched ribs. Reference and text-book: Burr and Falk's *Metallic Bridges.*

Pre-requisite: Mechanics **101-102.**

62—Graphic Statics. 2 hours lectures. 1 afternoon of problem and design work in the drawing academy. Professor WILLIAMS.

For students in Civil Engineering—Equilibrium polygon, and polygonal frames for all systems of loads—Graphical representations of shears and moments for both non-continuous and continuous beams—Fixed and moving loads—Lines of influence—Applications to bridge and roof trusses. Reference and text-book: Burr and Falk's *Influence Lines.*

Pre-requisite: Mechanics **101-102.**

64—Graphic Statics. 1 hour and 1 afternoon for mining engineers and metallurgist. Professor WILLIAMS.

An abridged course, covering the subjects taken in Course **62.**

Pre-requisite: Mechanics **101-102.**

71—Surveying between the Third and Fourth Years. Field work and office work. 4 weeks. Professor LOVELL, Mr. FOOTE and Assistants.

Railroad Surveying—Reconnaissance—Prelimary survey—Location—Cross-sectioning—Computations—Economic comparisons from construction and operation standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, earthwork quantities, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: **51-52** and **25.**

75—Hydraulics. 4 hours lectures, with conferences and problems. Professor BLACK.

Flow of water through orifices—Time required for discharge of canal locks and similar volumes—Weir discharge and gauging by weirs—Gauging of water for systems of irrigation—Flow through and discharge of pipes—Design of pipe systems for city waterworks—The Venturi meter—Flow in and discharge of open canals and rivers—Gauging of streams by current meters, floats and other means—Back-

water—Flow of compressible fluids. Text-book: Merriman's *Hydraulics.*

Pre-requisite: Mechanics 102, Math. 5.

76—Hydraulics. 2 hours lectures and recitation. Professor BLACK.

For students in Mining Engineering—Course 75 abridged.

Pre-requisite: Mechanics 102, Math. 5.

77—Hydraulics. 2 hours lectures. Professor BLACK.

For students in Electrical Engineering—Similar to course 75, but shorter. In addition it deals with the general considerations of rainfall, evaporation, percolation, run-off, net yield and storage; conduction of water from source to power-house, hydraulic losses and effective head on wheel; estimation of power. Text-book: Merriman's *Hydraulics.* Reference book: Turneaure and Russell's *Public Water Supplies.*

78—Hydraulics. 2 hours. Professor BLACK.

For students in Mechanical Engineering—Same as 76.

85—Foundations. 2 hours lectures, with frequent conferences and continuous work in design. 1 afternoon of problem and design work in the drawing academy. Professor BURR.

Earth foundations—Foundations for buildings—Safe loads on masonry and foundation beds—Pile driving and pile foundations—Safe loads for piles—Protection and preservation of piles and timber—Sheet piling and coffer-dam methods—Pneumatic foundations and caisson work—Open dredging—Bridge piers of masonry and cylinders—piers for deep foundations—Methods of working in quicksands—Tunneling. Reference books: Patton's *Foundations* and Baker's *Masonry and Foundations.*

Pre-requisite: 57-58, Geology 18.

87-88—The Design and Construction of Bridges, Roofs, and Buildings. 2 hours lectures and recitations, with frequent conferences and continuous work in design. 1 afternoon of problem and design work in the drawing academy. Professors BURR and WILLIAMS.

Railway and highway bridges—Pin and riveted connections—Single and multiple system of bracing—The design of details for bridges, roofs, and buildings—Floors for railway and highway bridges—The design and operation of draw-bridges, including engines, locking, lifting, and turning machinery—Cantilever structures—Wind roads and stresses—Single and double-track viaducts or trestles in iron, steel, and timber—Lateral and transverse systems of bracing—The design and construction of elevated railroads—The complete designs of railway structures, with estimates of cost—The erection of iron, steel, and timber structures, including the cost of erection. First half-year only for sanitary engineers. Reference and text-books: Burr and Falk's *Influence Lines;* Burr and Falk's *Metallic Bridges.*

Pre-requisite: 53-54, 61-62.

89-90—Railroad Engineering. 3 lectures. 5 hours of problem and design work in the drawing academy. Professor LOVELL and Mr. FOOTE.

Location, construction and operation—Train resistance, sources and probable value—Curvature and grades, their relation to velocity and maximum train-load—Effect of momentum—Reduction of grades at

starting points—Balance of grades for unequal traffic—Study of annual reports—Analysis of operating expenses—Cost of operating, including maintenance, per train mile—Itemized statements of costs and percentage to total cost—Cost of extra distance, curvature, rise and fall, or of additional trains—Effect of roadbed on cost of running trains—Justifiable expenditure in construction to save one mile of distance, one degree of curvature, one foot of rise and fall, or to reduce ruling grade .1% per daily train per year—Pusher grade for one or more assistant engines—Economical use of pusher grades—Cost of excessive or limiting curvature—Value of additional traffic—Principles to follow in locating new lines—General policy of improvements in old lines—Principles in design and construction of railroad yards and terminals—Computations and detail drawings of turnouts, slip switches and ladder tracks—Development and present practice in block signalling and interlocking, with problems in design and estimates of cost of installation—Classification and cost of earthwork—Graduation, cross section in excavation and embankment, and protection of slopes—Ordinary and extraordinary methods of drainage—Water supply, its quality, storage, and delivery—Principles of construction of wooden trestles and masonry culverts, including preparation of standard plans and estimates of cost—Ballast—Track, track accessories and maintenance of way details—Organization—Management. Reference books: Wellington's *Railway Location*—*Elements of Railroad Engineering*, Raymond—*American Railway Transportation*, Johnson—*The Block System*, Adams—Camp's *Notes on Track*—Dewsnap's *Railway Organization and Working*.

Pre-requisite: 71.

94—The Design and Construction of Sewers, and River and Harbor Improvements. 2 hours lectures, recitations, problem and design work. Professor Black.

Sewerage and surface drainage of cities and towns—Separate and combined systems of sewers—Capacities of mains and branches—Catch basins—Manholes—Chimneys or ventilators—Flush tanks—Outfalls—Grades—Flow or discharge of sewers—Construction. River and Harbor Improvements—Jetty system of river improvements—Scouring action of currents—Erosion of river banks—Dams for improvement of river navigation—Breakwaters—Dykes—Groins—Mattress work—Docks—Harbor works—Iron piers—Estimates of cost. Text and reference books: *Separate System of Sewerage*, Staley and Pierson—*Sewer Design*, Ogden—*Flow of Water in Open Channels, Pipes, etc.*, Flynn.

Pre-requisite: 26, 59, 75.

95—Engineering Contracts and Specifications. Mr. Church.

An elementary course dealing with the more common rules governing the formation, interpretation and discharge of engineering contracts, and the rights, liabilities and remedies of the parties thereto; including the preparation and criticism of specifications.

96—Principles of Hygiene, Sanitary Science and Public Health. 3 hours.

Health and disease; the germ theory of disease; dust and its dangers; infection and contagion; drinking water, ice, milk, vegetables, shell-fish, etc., as vehicles of disease; flies, fleas and other disease car-

riers; general problems of public health and sanitation. Personal hygiene.

Pre-requisite: Civil Engineering 57*a* and 57*b*.

98—**Water-Supply and Irrigation Engineering.** 2 hours lectures, recitations, problem and design work. Professor BLACK.

Rainfall and storage—Flow of streams—influence of soils, elevation, geological character of water-shed—Methods of supply, gravitation, pumping from rivers or natural underground storage, flow from the latter, underground flow, wells—Reservoir construction—Distributing system. House supply and wastage. Irrigation of land—Amounts and periods of application—Construction of, and flow through, diversion and distributing canals. Text-book: *Public Water Supplies,* Turneaure & Russell.

Pre-requisite: 26, 59, 75.

99-100—**Graduation Thesis.** A project or thesis on some civil engineering subject, approved by the head of the department, is required of every candidate for the degree of Civil Engineer.

Advanced Courses

The minor subjects in the department of Civil Engineering for the University degrees of Master of Arts and Doctor of Philosophy (those courses which fulfill the residence requirements) are the following:

153-154—**Elasticity and Resistance of Minerals.**

257-258—**Elastic and Masonry Arches.** Open to those who have taken 57-58. Conferences, reading and design work, as required.

275-276—**Hydraulics** (75 with additional reading).

285-286—**Foundations,** including theory of earth pressure (85 with additional reading).

287-288—**Long Span Bridges.** Open to those who have taken Civil Engineering 87-88. Conferences, with reading and design work as required.

The major subjects for the same University degrees are the following:

259-260—**Sanitary Engineering.** Pre-requisite: Courses 59, 94, 98.

277-278—**Hydraulic Engineering,** including the hydraulics of rivers and power plants and municipal water-works.

279-280—**Municipal Engineering,** including water-works, sewers and sewage works, streets and other public works and their administration.

289-290—**The Engineering of Structures,** including long span bridges and deep foundations, with methods of building them, and advanced work in Elasticity and Resistance of materials.

DRAFTING

1-2—Drafting. 1 hour lecture and 14 hours drafting for one half-year. Professor MAYER, Mr. MILLER, Mr. HARRINGTON, and Mr. BEANS.

(*a*)—Elements of mechanical drafting—Use of instruments; plane problems; freehand lettering; dimensioning;

(*b*)—Projections—Orthographic projection; intersections; developments; problems in descriptive geometry; isometric projection; cabinet projection;

(*c*)—Machine drafting—Conventional signs for materials of construction; sketching of machine details. Working drawings; tracings; blue printing;

(*d*)—Topography—Conventional signs; hill shading; mapping.

3-4—Descriptive Geometry. 3 hours for one half-year. Professor MAYER, Mr. MILLER, and Mr. HARRINGTON.

Problems on point, line, and plane; classification of surfaces; tangent planes to single curved surfaces and surfaces of revolutions; interesections; developments; warped surfaces.

5-6—Drafting. 6 hours drafting for one half-year. Professor MAYER and Mr. MILLER.

(*a*)—Graphics—Shades and shadows; perspective;

(*b*)—Stone cutting—Buttress; wing-wall; arches.

Pre-requisite: Drafting 1-2, 3-4.

7-8—Drafting. 6 hours drafting for one half-year. Professor MAYER, Mr. MILLER and Mr. HARRINGTON.

(*a*)—Structural drafting—Standard rolled sections; conventional riveting signs; standard connections; methods of framing and detailing structural work; beams; columns; plate girder; roof trusses; bridge details;

(*b*)—Machine drafting—Working drawings; tracing and blue prints of machine details; boiler and engine-room layouts, etc.

Pre-requisite: Drafting 1-2, 3-4.

Equipment

The drafting rooms and offices, situated on the fourth floor of the Engineering building, are equipped with a standard form of drafting table, and have a seating capacity for 175 students.

The collections of the department contain a complete set of models illustrating problems in projections and descriptive geometry, as well as the usual charts, blue prints, and models for use in the lecture and drafting rooms. A special feature of the collection is a full set of Olivier models illustrating the warped surfaces and problems in intersections and tangencies.

ECONOMICS

Economics 2. 3 hours a week during the second term. Professor SEAGER and Dr. AGGER.

Introduction to Economics. Lectures, reading and text-book discussion. In this course the fundamental principles of economics will be studied with particular reference to their application to current

economic and social problems in the United States, and with special regard to the needs of students in engineering. Third-year students in Electrical and fourth-year students in Mechanical Engineering.

ELECTRICAL ENGINEERING

1.—Elements of Electrical Engineering. 2 hours per week. Professors ARENDT and MORECROFT.

General Principles of Electricity and Magnetism with examples of their application.

STATIC ELECTRICITY—Production, indications of presence, electroscope and electrometer, law of inverse squares, conductors, electrification by contact and by electrostatic induction, Leyden jars and condensers.

MAGNETISM—Occurrence in nature, laws of magnetic force, making of permanent magnets, terrestrial magnetism, etc.

ELECTRICAL CURRENTS—Work of Galvani and Volta, production of currents, electrical couples and polarity, primary batteries, resistance and conductance, laws of resistance, Ohm's law, international units of resistance, voltage and current, development of heat by currents, Joule's law, international units of power and energy, incandescent lamps, hot wire instruments and the electric arc.

ELECTROMAGNETISM—Oersted's discoveries, magnetic effects of electrical currents, galvanometers, dynamometers, voltmeters, ammeters, wattmeters. Faraday's discoveries, electromagnetic induction, its laws and applications, direct and alternating currents, self and mutual induction, unit of inductance, electromagnetic terms, electrodynamic actions, magneto-motive-force, electromagnetic and international units, index notation, flux density, permeability, magnetic and non-magnetic materials, magnetization curves, hysteresis, eddy currents, residual magnetism, magnetic polarity and circulation of currents, electromagnets and polarized mechanisms.

ELECTROSTATICS—Potential, electrostatic voltmeters, di-electric capacity, condensers, discharge phenomena and atmospheric electricity.

ELECTRO-CHEMISTRY—Conductivity of liquids, electrolysis, laws of chemical action, electro-metallurgy and storage batteries. Text-book: Thompson's *Elementary Lessons in Electricity and Magnetism.*

Pre-requisite: Physics 3-4.

2—Elements of the Dynamo. 2 hours per week. Professors ARENDT and MORECROFT.

A general consideration of the principles and parts of Dynamo Electric Machinery. History, definition of dynamo and motor, reversibility of functions, magnetic field, magneto-motive-force, hysteresis, elementary dynamo, generation of E.M.F., collector rings and commutator. Parts of the dynamo; the magnetic circuit, materials and function. The armature core: materials, eddy currents, forms, construction. The armature winding: material, function, multiplication of electro-motive-force, types. The commutator: materials and construction. Brushes: function, materials and supports. Field frame: materials, forms, development of magnetic flux, windings, magnetic leakage. Armature reaction: cause of, back and cross ampere turns, brush shifting, sparking at brushes and remedies. Action of different types of dynamos, and typical forms. Text-book: Crocker's *Electric Lighting,* Vol. I.

Pre-requisite: Physics 3-4, E. E. 1.

4—Electric Distribution. 2 hours. Professors SLICHTER and ARENDT.

For E.M., C.E., and Met.E. students. Principles and Methods of transmitting, distributing and controlling direct currents. Introductory, direct current series and parallel systems, feeders and mains, voltage regulation, networks, high voltage d.c. systems.

Principles of alternating currents, self and mutual inductance, capacity, impedance, effective values of current and voltage, phase angle and power factor. Text-book: Crocker's *Electric Lighting,* Vol. II.

Pre-requisite: E. E. **1** and **2.**

52—Design of Direct-Current Machinery. 2 hours lecture and 1 afternoon drafting room. Professors SLICHTER and ARENDT.

Application of electrical and mechanical theory to the design and calculation of D. C. machinery with a complete and original design of a dynamo or motor in accordance with specifications, requiring all calculations, working drawings and blue prints. Text-book: Thompson's *Design of Dynamos.*

Pre-requisite: E. E. **1, 2,** and **101.**

54—Design of Alternating-Current Machinery. 2 hours and 1 afternoon per week. Professors SLICHTER and ARENDT.

The application of alternating current theory and practical data to the calculation and design of alternators, transformers, induction motors and other alternating current apparatus. Reference books: Arnold's *Wechselstromtechnik;* Thompson's *Dynamo Electric Machinery,* Vol. II, and McAllister's *Alternating Current Motors.*

Pre-requisite: E. E. **52, 103** and **105,** Mechanics **108** and **109.** Parallel course: Mechanics **110.**

72—Direct-Current Laboratory. 1 afternoon laboratory work. Professor MORECROFT and Mr. HEHRE.

Short Course for students in Mining, Metallurgical, Civil, Chemical Engineering and Chemistry. The experiments cover the following: Fall of Potential, Resistance determinations, Study of various types of D. C. generators, their connections and characteristics of operation. Working of generators in parallel. Study of various types of motors, their connections, characteristics of operation and determination of commercial efficiency by brake tests. The results of these experiments are handed in as reports which are returned promptly to the students, with comments and corrections. Text-book: Sever's *Electrical Engineering Experiments, etc.*

Pre-requisite: E. E. **1** and **2.**

73—Direct-Current Laboratory Work. 1 afternoon per week. Professor MORECROFT and Mr. HEHRE.

Short course for students in Mechanical Engineering. Same as 72.

Pre-requisite: E. E. **1** and **2** with parallel course E. E. **101.**

75—Alternating-Current Laboratory. 1 hour lecture and 1 afternoon laboratory practice. Professor MORECROFT and Assistants.

Short course for Mining and Mechanical Engineering students. The experiments cover the following: Study of Elementary phenomena of alternating current circuits, with determination of inductance, capacity, impedance, true watts, apparent watts and power factor. Study

of an Alternator, its operation, characteristic curves and wave form. Transformers: Their operation and commercial efficiency. Induction motors: Characteristics and efficiency by brake tests. Synchronous motors, their operation under various conditions and characteristic curves. Rotary converters, operation under various conditions of load and power factor (direct and inverted). Alternators in parallel, division of load and conditions for maximum economy. The student is required to prepare a report upon each experiment which is promptly corrected and returned to him for his instruction. Text-book: Townsend's *Short Course in Alternating Current Testing.*

Pre-requisite: E. E. 72 or 73 and 4 or 104.

76—Alternating-Current Laboratory. 1 hour lecture and 1 afternoon per week. Professor MORECROFT and Assistants.

Short course for Civil Engineers. Same as 75.

Pre-requisite: E. E. 72 or 73 and 4.

98—Thesis. Original investigation of and report on some problem of Electrical Engineering, approved of by the head of the department. Optional.

101—Dynamo and Motor Practice. 2 hours. Professor SLICHTER.

A course of lectures parallel to and descriptive of D. C. laboratory work. Short circuits and protective devices. Instruments: construction and use. Armature: e. m. f. current. resistance of, voltage drop in, windings and connections. Commutator: function, construction, heating, sparking, collecting brushes and holders. Magnetic circuit: calculation of flux and field windings. Heating of field and armature. Characteristics of the various types of generators and methods of regulation. Motors, theory of action and types. Methods of control and speed regulation. Losses and determination of efficiency by brake, stray power and pumping back methods. Text-books: Crocker's *Electric Lighting,* Vol. I, and Sever-Townsend's *Laboratory and Factory Tests in Electrical Engineering.*

Pre-requisite: E. E. 1 and 2.

103—Electric Power. 3 hours. Professors SLICHTER and ARENDT.

(For E. E.) Electric motors, their action, control and application. Introductory. Classification of work requirements. Shunt Motors: Characteristics, predetermination of action, and efficiency, methods of speed control and regulation, rheostatic, field weakening, multiple voltage, double armature and teaser system. Series Motors: Connections, predetermination of characteristics and efficiency. control: rheostatic, field weakening, double armature and series parallel. Compound motor, characteristics and methods of control. Alternating current motors introductory. Commutator A. C. motors, series and repulsion types, characteristics and control. Synchronous Motors, characteristics and control. Induction Motors, single and polyphase, characteristics, methods of starting, speed control and regulation. Electric Drive, advantages of and application to machine tools, cranes, elevators, presses, pumps, fans, wood working and mill work. Text-book and Electric Motors by Crocker and Arendt.

Pre-requisite: E. E. 101, 104, 173 and 174.

103A—Electric Power. 2 hours. Professors SLICHTER and ARENDT.

Electric Motors, their action, control and application. **103** abridged for Mechanical Engineering Students.

Pre-requisite: E. E. **101, 104** and **73.**

104—Electric Distribution. 3 hours. Professors SLICHTER and ARENDT.

Principles and methods of transmitting, distributing and controlling direct and alternating currents. Introductory, Physical properties of conductors, direct-current series and parallel systems of distribution, feeders and mains, voltage regulation, three-wire systems, high voltage direct-current systems, network systems.

Principles of alternating currents, study of wave shapes, inductance, capacity, phase angle, effective values of electromotive force and current, power factor, resonance, simple circuits, parallel circuits, line inductance and distributed capacity, calculation of single phase circuits. Text-book: Crocker's *Electric Lighting,* Vol. II.

Pre-requisite: E. E. **1, 2,** and **101.**

105—Electric Plants. 2 hours. Professors SLICHTER, ARENDT and special lecturers.

Electric power systems, including translating, controlling and transmitting equipments. Constant potential and constant current transformers, principles, efficiency, regulation and protection. Polyphase systems of generation, two phase and three phase, economy of generators, of transmission, and conversion from one system to another. Calculation of alternating current transmission lines, regulation of voltage and power factor of systems. Switch-boards, materials, apparatus used upon, location and types. Line construction and protection, pole lines, cable and conduit systems. Text-book: Crocker's *Electric Lighting,* Vols. I and II.

Pre-requisite: E. E. **101** and **104.**

106—Management of Electric Plants. 2 hours. Professors SLICHTER and ARENDT and special lecturers.

Management of electric plants and industrial enterprises. Electric illumination, methods of charging for electric power, operating expenses, sources of income, organization and administration of corporations, reports, specifications, contracts, insurance regulations, patents and statistics.

Pre-requisite: E. E. **103, 104** and **105.**

110—Telegraphy and Telephony. 2 hours. Professor ARENDT.

The principal methods and instruments employed in telegraphy, telephony and electric signalling. **Telegraphy:** Historical review, Morse systems, relays and sounders, earth circuits, station equipments, repeaters, differential and polarized relays, duplex systems, quadruplex systems, telegraphy from moving bodies, recording systems, submarine cables and telegraph circuits. **Wireless telegraphy:** Generation of electrical waves, simple transmitting and receiving apparatus. **Telephony:** Historical review, Bell's work, the magneto-telephone, the microphone and carbon transmitters, use of induction coils, call methods, series and parallel circuits, subscriber's equipment, line disturbances, common battery systems, subscriber's and exchange equipment, party lines, automatic systems, combined telegraphy and telephony. Text-books: Maver's *American Telegraph Practice* and Miller's *American Telephone Practice.*

Pre-requisite: E. E. 104.

112—**Electric Railway.** 2 hours. Professor SLICHTER.

Special instruction in calculation, installation and operation of electric railway systems. Historical review and early development. Train resistances due to tracks and bearing surfaces, curves, grades, and air. Acceleration and breaking. Speed time curves. Motors for railway work. Controllers. Distribution systems, track construction, bonding and electrolysis. Trucks, wheels and car bodies. Conduit, storage battery and third rail systems. Electric locomotives and multiple unit control. Testing railway equipments. Financial considerations.

Pre-requisite: E. E. 104.

173-174—**Direct-Current Laboratory.** 6 hours (2 afternoons). Professor MORECROFT and Mr. HEHRE.

A series of experiments for electrical engineering students in the operation and testing of direct current machinery. The work comprises the following: 1. Practice in the accurate use of voltmeters and ammeters for the measurement of electromotive force and current. Determination of resistance of the electrical circuits of electrical machinery by "drop," comparison and direct deflection methods. Use of Wheatstone bridge for determination of high resistance. 2. Generators: Preliminary study to bring out relations between, speed, field strength and voltage. Operation of shunt, series and compound-wound generators with determination of characteristic action of each type. Distribution of potential around commutator and distorting effects due to armature reactions. Heat runs to determine load capacity and efficiency determinations by means of stray power and "pumping back" tests. 3. Motors: Function and operation of starting boxes, study of motors, existence and measurement of c.e.m.f., operation of shunt, series, compound and differentially wound motors, determination of speed-load curves of each type. Efficiency tests by brake and stray-power methods. 4. Operation of shunt and compound-wound generators in parallel, methods of connecting, distribution of load, effects of individual differences, etc. 5. Constant Current Dynamos: Comparison of characteristics of constant potential and constant current circuits, methods of governing constant current machines, action under variable loads, control of series circuits, regulation of arc lamps. Text-book: Sever and Townsend's *Factory and Laboratory Tests in Electrical Engineering.*

Pre-requisite: E. E. 1 and 2. Parallel course: E. E. 101.

175-176—**Alternating-Current Laboratory.** 1 lecture hour and 6 hours laboratory practice (one whole day) first term, 1 hour lecture and 6 hours laboratory practice (2 afternoons) second term. Professors PUPIN and MORECROFT with Assistants.

A series of experiments for electrical engineering students illustrating the fundamental theory and applications of alternating current phenomena. 1. Alternating current circuits: determination of inductance, capacity, impedance, phase relations, true and apparent watts and power factor. 2. Alternators: operation at different power factors, magnetization curves, determination of losses and synchronous impedance, field compounding, etc. 3. Synchronous Motors: Methods of synchronizing, efficiency, action under varying conditions of load and field current. 4 Rotary converters: Methods of starting, operation direct and inverted, compounding, determination of voltage ratios and calculation of efficiency. 5. Alternators in Parallel: division of load, cross currents and adjustment of excitation for maximum

economy. 6. Transformers: operation, determination of losses, regulation, heating and efficiency. Use as induction regulators and phase changers. 7. Wave Forms: determination of wave shapes and phase relations of electromotive-force and current in relative and non-relative circuits as well as in the primary and secondary circuits of transformers by instantaneous contact and oscillograph methods. 8. Resonance: by means of inductance and capacity in series, by inductance and leading current produced by synchronous motors, with application to transmission lines and rotary converter regulation. 9. Induction Motors: methods of starting, characteristic curves, determination of losses and efficiency by brake tests, application of circle diagram and use as frequency changer. 10. Induction Generator: operation and determination of the external characteristic. Text-book: Sever and Townsend's *Factory and Laboratory Tests in Electrical Engineering.*

Pre-requisite: E. E. 104 and 173-174. Parallel courses: E. E. 105 and Mech. 109.

177—Instrument Laboratory. 1 hour lecture and 2 afternoons laboratory work. Professor MORECROFT and assistant.

Calibrating of commercial measuring instruments and advanced electrical measurements, as follows: 1. Calibration of ammeters by comparison with laboratory standards, Kelvin balances, Siemens' dynamometers, and potentiometers. 2. Calibration of voltmeters. 3. Calibration, adjustment and determination of constants of A. C. and D. C. watt-hour meters, by various methods. 4. Determination of resistances: by Wheatstone bridge and potentiometer methods. 5. Measurements of Inductance and capacity. a. By comparison with standards using A. C. bridge. b. By absolute method, including determination of constants of ballistic galvanometer. 6. Magnetic measurements. Determination of coefficient of magnetic leakage of generator or motor. Determination of the permeability of samples of iron and steel. a. By Hopkinson's method. b. By Ewing double bridge method. c. A. C. voltmeter method. d. Direct reading voltmeter method. Determination of Hysteresis by Hopkinson, Double bridge, Voltmeter and Ewing tester methods. 7. Storage Battery Testing. Determination of normal rate of discharge, capacity and efficiency at normal rates, capacity at various rates. Constant current and constant potential methods of charging, weight efficiency and losses on standing. 8. Photometry. a. Proving gas meters and determination of candle power of gas against standard candles. b. Candle power incandescent lamps using standard candle. c. Distribution of light from an incandescent lamp, using secondary standard. d. Determination of mean spherical and mean hemispherical candle power of an incandescent lamp. e. Relations between voltage, candle power, efficiency and life of incandescent lamps. Arc lamp photometry. 9. Cable Testing. a. To determine insulation resistance; induction and capacity. b. To determine location of faults. Text-book: Sever and Townsend's *Factory and Laboratory Tests in Electrical Engineering.*

Pre-requisite: E. E. 173-174.

Graduate Courses

101, 104 and 173-174—Dynamo and Motor Practice, Electrical Distribution and D. C. Electrical Laboratory. 2 hours and 5 hours laboratory.

Pre-requiste: E. E., 1 and 2.

175-176—**Alternating-Current Laboratory.** With Mechanics 109 and 110. 4 hours first half-year, 2 hours second half-year and 2 afternoons.

Pre-requisite: E. E. 104, 173-174, and Mechanics 108.

103, 105, 106, 175-176 and 177—**Electric Motors, Electric Plants, Management of Plants, and Electrical Laboratory.** 8 hours lecture, 4 afternoons first term; 3 hours lecture, 2 afternoons second term.

Pre-requisite: E. E. 104, 173-174.

201-202—**Special Problems and Original Investigations** in Advanced Electrical Engineering, with conferences and laboratory work as required.

Pre-requisite: All courses for the degree of Electrical Engineer.

NOTE—Attention is called to the advanced theoretical courses offered by Professor Pupin in the Department of Mathematical Physics. (See statement of Department of Physics.)

GEOLOGY

4—**Petrography.** 2 afternoons two months of the second half third year. Professor BERKEY.

A short course in the microscopic study of rocks.

Pre-requisite: Mineralogy 6.

6—**General Geology.** 6 hours lectures, second term, second year. Professors KEMP and BERKEY.

First two months physical geology, with practical work in the rock collections under the lithological part of the subject; second two months, stratigraphical and historical geology, involving laboratory work with type fossils and collections illustrating the geology of the United States. Text-books: Kemp's *Hand-book of Rocks;* Scott's *Introduction to Geology.*

Pre-requisite: Mineralogy 1.

16—**Index Fossils.** 1 hour lectures, 8 hours laboratory, second term. Professor GRABAU and Mr. HYDE.

A study of the invertebrate fossils characteristic of the various geologic horizons of North America.

18—**General Geology.** Professor BERKEY.

A general discussion of dynamical, structural and historical geology, with practical work in the rock collections and assigned field work on Saturdays during the last six weeks. Special course during the second half-year for students in Civil Engineering only.

19—**Physiographic and Applied Geology.** 3 hours lectures and laboratory by appointment, first term. Professor BERKEY.

A study of topographic and structural features and their representation on maps; application of geologic principles to engineering enterprises; water supply; illustrative problems. Open to students who have completed a course in general geology.

20—Rocks and Soils. 2 hours lectures and recitations, second term. Professor BERKEY.

A study of the residuary products from rock decay; types of soils; soil classification and mapping. Open to students who have completed a course in general geology.

51. 2 lectures per week. Professor GRABAU.

Principles of the formation of sedimentary deposits, involving a discussion of marine and continental sedimentation, the criteria by which various sediments can be recognized, methods of preservation of organic remains, and the principles of geographic and geologic distribution of organisms. Principles of correlation. Text-book: Grabau's *Principles of Stratigraphy.*

52. 2 lectures per week, second term. Professors GRABAU and BERKEY.

A discussion of secondary structural features; principles of formation of folds, faults, etc. Vulcanism, metamorphism, secondary mineralization.

105-106—Economic Geology. 3 hours lectures and one elective conference, third year. Professor KEMP.

First half-year, discussion of the general features and formation of ore bodies, followed by a description of the deposits of the ores of iron, copper, lead, zinc, silver, gold, and the lesser metals, with especial reference to North America; second half-year, a description of the distribution and occurrences of coal, petroleum, natural gas, asphalt, building-stone, water supply, salines, and minor minerals. Text-book: Kemp's *Ore Deposits of the United States and Canada,* and lecture notes privately printed.

Pre-requisite: Geology 6.

107-108—Invertebrate Palæontology. 2 hours lecture and 4 hours or more laboratory. Professor GRABAU and Mr. HYDE.

First part of the course deals with the principles of palæontology; methods of study of the ontogeny of hard parts of animals, and the laws of morphogenesis. This is followed by a consideration of the classes of invertebrates important from a palæontologist's point of view, emphasis being laid on the features which show genetic relationship. Special attention is given to groups whose evolution has been worked out. Text-book: Zittel-Eastman, *Text-book of Palæontology,* Vol. I.

110—Geological Examinations and Surveys. 2 hours, second half fourth year. Professor KEMP.

A discussion of the methods of systematically recording and interpreting geological phenomena; and of the organization and scope of geological surveys on a larger scale. This is followed by a sketch of the history and results of state and national geological surveys in this and other countries; and of other sources of detailed information regarding local geology.

Pre-requisite: Geology 105-106.

112—Field Geology.

A summer course of a week or ten days near New York for students in the course of Mining Engineering. Graduate students in the

department may join the party. Instruction is given in the field in observing, recording, and interpreting geological phenomena and in the preparation of maps and sections. A written report is required.

201-202—Petrology. 2 hours lectures and 4 hours laboratory, fourth year. Professors KEMP and BERKEY.

A discussion of the origin, microscopic structure, and mineralogical composition of the crystalline rocks, and of metamorphism.

Pre-requisite: Mineralogy 6.

LAW

Law 2—Business Law. 3 hours per week in the second term. Dean KIRCHWEY and Mr. PARKS.

A discussion of the elementary rules of law governing business transactions, including real property, contracts, agency, commercial paper, sales, suretyship, bailments, torts, partnership, corporations. The rules of law are developed and illustrated by examples taken from the reports, and dealing with situations such as engineers have in fact met and are apt to meet in the practice of their profession.

MATHEMATICS

1—Algebra. Professors MITCHELL, FITE, and HAWKES, Dr. GROVE, Mr. MAXSON, Mr. REDDICK and Dr. LENNES.

Includes such topics as determinants, complex numbers, the theory of equations, undetermined coefficients involving the use of finite series, and partial fractions.

Section 1, T., and Th. at 9.
Section 2, T., and Th. at 10.

Pre-requisite: Entrance Mathematics.

2—Differential Calculus. Professors MITCHELL, HAWKES, and FITE, Dr. GROVE, Mr. MAXSON, Mr. SICELOFF, Mr. REDDICK, and Dr. LENNES.

An introduction constituting with 65 (see below) one course in the calculus. Differentiation of algebraic and transcendental functions, with applications to geometry, maxima and minima and mechanics.

Section 1, T., and Th. at 9.
Section 2, T., and Th. at 10.

Pre-requisite: 1 and 3.

3-4—Analytical Geometry. Professors MITCHELL, FITE, and HAWKES, Dr. GROVE, Mr. MAXSON, Mr. SICELOFF, Mr. REDDICK, and Dr. LENNES.

Introduction to algebraic geometry, dealing with such topics as coordinate systems, transformations, loci and their equations, the straight line, circle, parabola, ellipse, hyperbola, the geometric interpretation of the general equation of second degree, and the elements of three-dimensional geometry. First year.

Section 1, M. W., and F. at 9.
Section 2, M. W., and F. at 10.

Pre-requisite: Entrance Mathematics.

65—Differential and Integral Calculus. Professors KEYSER, FISKE, MITCHELL, FITE, and HAWKES, Dr. GROVE, and Mr. REDDICK.

Continuation of 2. Further study of the differential calculus; the principles of the integral calculus; applications to geometry, physics and mechanics. First half of second year.

Section 1, M. T., W., Th., and F. at 10.

Section 2, M., T., W., Th., and F. at 11.

Pre-requisite: 1, 2, 3-4.

MECHANICAL ENGINEERING

11-12—Steam Power Machinery. 3 hours, 1 afternoon in the second term. Professor LUCKE, Mr. GUNN and Mr. PARR.

Functions, Forms and Principles of Operation of the Typical Steam power Plant Units, Auxiliaries and Connecting Elements—Methods of receiving, storing and firing coal, coal handling machinery, grates, stokers and furnaces for the combustion of coal; smokeless combustion and smoke ordinances; flow of gases through boilers, flues, dampers and the generation of necessary draft by chimneys, fans and steam jets. The construction and operation of boilers, boiler settings and foundations. Methods and apparatus for feeding water to boilers. necessary boiler attachments and trimmings. Flow of steam from boilers to engines and the grouping of engines and boilers, piping, valves, fittings and pipe covering. The heating of boiler feed water in feed water heaters and economizers. Purification of boiler feed water and effects of impure water on the boiler. Boiler strength tests and inspection laws. Boiler explosions. Steam pipe condensation and drainage. Steam traps, separators, steam superheating and superheaters. Condensing operation of steam engines by jet, surface, ejector and barometric condensers. Necessity for and types of circulating, hot-well and dry vacuum pumps and cooling towers. Typical steam engines and the variations in form and character of their important parts. Engine valves of simple and complete form, relation between construction of engine and valve gear to its economy. Special valve gears for high economy, for reserving and for power control. Regulation of engines and engine governors. Relation between engine construction, foundations, vibrations and balancing. Steam turbines. Typical steam plant arrangements for various special and standard conditions.

Afternoon work in laboratory, power house and drafting room, sketching apparatus, setting valves, plotting diagrams and demonstration of principles of operation taught in class. Second year Mechanical Engineering.

Pre-requisite course: Physics 3.

13-14—Steam Power Machinery. 3 hours. Professor LUCKE and Mr. GUNN.

Short course adapted from M. E. 11-12. Second year Civil and Electrical; Third year Metallurgical, Chemical, and Mining Engineering; Fourth year Chemical.

Pre-requisite course: Physics 3.

17-18—Technical Thermodynamics. Professor LUCKE and Mr. GUNN.

Laws of Heat Generation by Combustion, Heat Transfer and Trans-

formation into Work—Relation between temperatures and quantities of heat. Units of heat. Effect of heat on solids, liquids, gases and vapors. Laws of heat transfer. Laws of surface evaporation, ebullition and condensation. Properties of saturated and superheated vapors. Combustion of fuels, calorific power, quantities of air for combustion. Temperature of combustion. Boiler efficiency and conditions affecting. Principles of chimney draft. Laws of expansion and compression of gases. Work and heat diagrams to pressure volumes and temperature entropy co-ordinates. Air and wet vapor compression. Expansion of steam by hypothetic, adiabatic and saturation laws and application to steam engine efficiency. Missing water in steam engines. Influence of cylinder condensation, re-evaporation, steam jackets, initial superheat, compounding and reheating on steam engine efficiency. Relation of boiler and engine performance. Free expansion laws and application to injector and steam turbine nozzles. Heat transformation by perfect gases. Hot air, gas and oil engine efficiency. Mechanical refrigeration. Effects of evaporation of ammonia and carbonic acid and expansion of air. Heat balances and combined efficiency of complex systems. Third year Mechanical, Electrical, and Civil Engineering; Third year Mining Engineering for first term.

Pre-requisite courses: Mechanics 102; M. E. 11-12 or 13-14.

19-20—Engine Design. 3 hours and 3 afternoons. Professor Rautenstrauch and Mr. Thomas.

Advanced Machine Design Based on the Thermal and Mechanical Problems Involved in the Design of a Steam Engine for Power, Economy and Regulation—Determination of ideal indicator card, probable M.E.P., piston speed, R.P.M., and displacement for required power, selection of single or multiple expansion construction from economy requirements, limits of clearance, cutoff, release, compression and admission for type of valve gear selected. Stresses due to steam and inertia in the principal parts. Forms and proportions of the parts determined by intensity, distribution and nature of the stresses, properties of the materials and conditions affecting maintenance. Determination of proportions of engine parts. Design of fly-wheels for limiting variation in velocity and analysis of resulting angular variation. Balancing the engine. Valve gears and governors, determination of the proportions of the valve for predetermined steam distribution, analysis of valve movements and moving gear. Graphic representation of the simultaneous events of valve opening, steam velocities and piston velocities. Analysis for the effect of the angularity of the rod. Equalizing the events of the valve. Analysis of the characteristics of the shifting eccentrics and the resultant variations in the valve events. Layout of the Corliss valve gear with single and double eccentric, and proportions of the mechanism. Steam engine governors, flyball and shaft governors, limits of movement, valve gear resistance. Proportions of the governor. Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. 39, 40, 11, 12, 17-18.

22—Gas Power Machinery. 4 hours and 1 afternoon. Professor Lucke, Mr. Gunn and Mr. Parr.

Theoretical and Practical Consideration Affecting the Generation of Power by Gas Engines, Including Oil Vaporization, Coal Gasification and the Design of the Machinery—Efficiency, M.E.P., displacement per minute per I.H.P. for reference diagrams. Limitations of external and internal heating. Methods of explosive and non-explosive internal

heating. Properties of explosive gas mixtures, air necessary, calorific power per cu. ft. of mixture; temperature of combustion, heat suppression, efficiency of combustion, pressure and volume effects, limitations of proportions, temperature of ignition, rate of propagation, the explosive wave. Critical examination of modern gas engine forms and functions of parts; means for mixing and proportioning, pressure regulators, ignition; governors, effects on the engine and mechanism; starting equipment; exhaust piping and muffling; effects of back pressure in the engine; cooling; preignition, effect of cooling on economy. Large blast furnace practice, methods of gas cleaning; blast furnace gas, quality. Large engine construction, and forms of parts. Producer gas practice; standard producer for anthracite and bituminous coal, characteristics; gas, variation in quality, effects on the engine; methods of blasting producers, auxiliary steam supply and steam consumption; efficiency and rate of combustion in producer; scrubbers and tar extractors. Carburetors and vaporizers for liquid fuel; petroleum distillates, crude oil and denatured alcohol, vapor tension curves for liquid fuels. Characteristics of modern forms of gasoline and oil engines, gas power plant arrangements, producer engines, their efficiency, coal consumption and comparison with steam plants.

Complete analysis of the rating, efficiency, regulation, forces acting in and strength of parts of a modern gas engine. Probable indicator card, inertia of reciprocating parts, wrist pin and turning effort diagram. Dimensions of all parts. Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. 19, 33.

25—Steam Power Plant Design. 3 hours and 3 afternoons. Professor LUCKE and Mr. GUNN.

Relation Between the Cost of Power and Thermal Efficiency of the Plant. Commercial Value of Refinements—Determination of engine and boiler ratings and corresponding efficiencies and probable coal and water consumption for plant on given load curve. Essential relation between processes and dimensions of the steam plant. Steam plant refinements for raising efficiency of part or complete plant and relations between dimensions and effect. Use of unit costs of apparatus in estimating, examination of cost sheets to determine prime unit of cost. Cost of power. Fixed and operating charges, ratio of each individual item to total and effect of labor and fuel rates, load factor and refinements on the fractional part. Value of refinements of design on basis of capitalized annual saving by comparing the cost of waste and the cost of its elimination, including all charges. Specifications and contracts; standard and special methods and forms for defining purchaser's requirements and builder's proposals, contracts, methods of power plant erection. Designing and erecting office organization and field systems.

The work consists in laying out a simple power plant for assigned units in the drafting room or the detailing of existing general plant drawings, preparation of the bill of materials, estimating the first cost, fixed charges, probable coal, water, labor and supply cost for an assumed load curve and total power cost. The plants so designed or detailed are exchanged by students and redesigned for an increase of 100 per cent. peak and 50 per cent. mean daily load and for the maximum power cost reduction by the use of plant refinements and auxiliaries when it can be shown that additions and alterations will pay. Specifications are written for the alteration and proposals submitted. Fourth year Mechanical Engineering.

Pre-requisite course: M. E. 96S.

31-32—Experimental Engineering. 1 hour and 1 afternoon. Mr. THURSTON.

Laboratory methods for the determination of experimental data. Derivation of physical laws from experimental results—Comparison of actual performance of machines with computed prediction and evaluation of unknown elements. Methods of approach for the solution of practical problems by experiment and computation. The work is illustrated by problems on the flow of liquids, gases and vapors, combustion, transfer of heat, steam generation and changes of state, transformation of energy, power generation and transmission, energy losses, thermal, hydraulic and mechanical. For each problem a preliminary report is submitted before the test, involving the analysis of the problem, the attempted prediction and the required test log, based on classroom explanations; this is incorporated with the tests results and an interpretation of differences between these and the prediction, including judgment of errors, to constitute the final report. The apparatus for this course includes: Pressure gauges, manometers, thermometers, pyrometers, indicators, tachometers, planimeters, barometers, weirs, channels, nozzles and orifices for water, steam and air, Pitot and Venturi tubes, steam, gas and water piping and meters, dynamometers, power scales, viscosimeters, flue gas apparatus, steam traps, hydraulic ram, steam injectors, air pump, hot air engine, duplex steam pumps, Pelton wheel, centrifugal pump, simple steam engine. Third year Mechanical Engineering. Texts: *Experimental Engineering*—Carpenter, *Experimental Engineering*—Pullen, *Lecture Notes.*

Pre-requisite courses: M. E. 11-12. Courses which are parallel to it: M. E. 17-18 and Mechanics 105.

33—Experimental Engineering (Continuation of Course 31-32). 2 hours and 1 afternoon. Mr. PARR and Mr. THURSTON.

The work of this course is the same in nature as 31-32, but the problems involve more difficult computations and more skilful manipulation of the apparatus. These problems are principally concerned with energy transformation, necessary and accidental losses and the determination of the conditions affecting performance of compound and triple expansion steam engines and pumps, operating condensing and non-condensing, with and without receivers, with and without reheaters. Hydraulic motors, one, two and three stage air compressors, with and without intercoolers, feed water heaters, fans, steam boilers, ammonia refrigerating machines, steam superheaters and condensers. Attention is also given to the commercial tests standardized by the Engineering Societies. Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. 31-32; M. E. 96S; M. E. 17-18.

36—Kinematics of Machinery. 2 afternoons. Mr. THOMAS.

Determination of Paths of Motion, Velocity, Acceleration and Kinetic Forces of the Moving Parts of Machines with the Resulting Reaction Forces of the Frame—Relative motions of machine parts and the determination of the rates of motion. Determination of space, velocity and acceleration diagrams with application to the steam engine, shaper and other standard mechanisms. Construction and use of diagrams for the determination of inertia forces and their distribution in each element of a machine. The layout of motions to specifications. Design of cams with special reference to the rate of change of velocity of the moving parts and the resultant inertia forces, resistances to motion and the continuous contact of cam and follower. Analysis

of link work, relative motions, inversions, adaptability to the accomplishment of specific kinds and limits of motion. Eccentrics and links for the transformation of kinds of motion; ratchet motion; running ratchets. Clutch and coupling mechanisms, connecting shafts in parallel and at an angle. Modification to permit of non-alignment. Toothed gearings. Justification of the cycloidal and involute curves in their application to gear teeth. The layout of tooth forms and the determination of the velocity ratios. Layout of bevel gear tooth forms by Tredgold's method. Approximate methods and practical rules for the layout of gear teeth. Determination of paths of contact, obliquity of motion, length of teeth, interferences in involute gearing. Determination of the necessary conditions for interchangeability in sets of cycloidal and involute gears and comparison of the system. Friction gears. Kinematics of belt drive. Open and crossed belts. Layout of belt drives and rope drives, sprocket wheels and chain drives, speed changing devices using wrapping connections. Text: *Kinematics of Machinery—Durley.* Second year Mechanical and third year Electrical Engineering.

Pre-requisite courses are Math. 3-4 and M. E. 59.

39-40—**Machine Design.** First term, 1 hour, 2 afternoons. Professor RAUTENSTRAUCH.

Analysis of stress in machine parts of standard form under varying conditions of service and the proportions of the machine elements to safely resist the resulting stresses—Application of the principles of Kinematics, Resistance of Materials, Design of Machine Elements, Shop and Foundry Methods to the design and analysis of complete machines. Examination of machines to determine the nature and distribution of the forces acting on and the resulting stresses and strains in each element due to kinetic and structural conditions. Selection of working stresses for machine parts subject to steady, repeated and reversed stresses. Selection of materials for machine parts based on their adaptability to the service and to the shop processes by which the part must be made. Determination of the proportions of machine parts subjected to tension, compression, and shear; bending and torsion; combined bending and tension, bending and torsion, torsion and compression, buckling action, and stresses due to eccentric loading and complex supports. Illustrated in the design of crank shafts, machine frames, housings and connecting rods. Gear wheels, pulleys, flywheels, springs, riveted joints, thin and thick cylinders, braces and stays, flat plate members, pressure joints, screws, belting, rope and chain drives for power transmission. Bearing surfaces, flat, cylindrical, pivot, ball, roller, thrust. Application of theory of elasticity to the more complicated elements. Grouping of machine elements into machines for functional operation, erection, adjustment, maintenance and repair and modifications demanded by facilities for manufacture. Design of machines to specification, with particular reference to modern requirements. Text: Spooner's *Machine Design.* Third year Mechanical Engineers, fourth year Chemical Engineers. Second term, 2 hours, 2 afternoons.

Pre-requisite courses: M. E. 36. Must parallel C. E. 53.

41—**Machine Design.** 1 hour and 1 afternoon. Mr. THOMAS.

A short course adapted from M. E. 39-40. Fourth year Civil and third year Electrical Engineering.

Pre-requisite courses: C. E. 53 for C. E. Must parallel C. E. 53 for E. E.

46—Water Power Machinery. 3 hours. Mr. Parr.

Principles of Design and Economy of Operation of Turbine Wheels and Water Power Plants—Action of water on curved vanes, forces developed and effect of impact, work done; centrifugal action. Theory of reaction turbines. Vane form and arrangement; total work done for axial, radial and mixed flow wheels; dependence of velocity of flow on speed of rotation; losses of energy due to friction in guide passages, wheel buckets and sluice, shock, leakage, residual velocity. Design of reaction turbines; relation between pressure and velocity of flow; methods of determining passage areas; radii of wheels, width and depth of buckets, number and thickness of vanes. Axial turbines, characteristics, forms and dimensions. Impulse turbines; essential principles and theory, advantages, ventilation of bucket, velocity of flow, available energy, efficiency. Axial impulse turbines, characteristics, forms and dimensions. Centrifugal action in axial flow, reaction and impulse turbines. Radial impulse turbines, inward and outward flow; forms, characteristics and dimensions. Descriptions of and experiments with turbines of various types. Existing water power plants. Modern governors for turbines; ideal action of direct acting governor and disturbing influences; essential principle of indirect acting governor; factors affecting regulation. Fourth year Mechanical Engineering and Fourth year Civil Engineering.

Pre-requisite courses: For Mechanical Engineering: M. E. 36, M. E. 33, C. E. 78; for Civil Engineers, M. E. 76, M. E. 78, C. E. 75.

52—Works Management. 2 hours. Professor Rautenstrauch, Mr. Going and Associates.

Manufacturing Organizations and Methods of Cost Accounting—Effect of methods of manufacture and capacity on systems of management of mills and factories. Analysis of the elements of factory accounting and determination of the factors entering into the cost of production. Methods for keeping record of the cost of labor and materials in the production of specific articles. The determination of establishment charges. Interpretation of costs and use of comparative values. Determination of costs and use of comparative values. Determination of the depreciation of buildings, machinery, patterns, drawings and other assets. Organization and functions of the departments of the business. Purchase of raw material and sale of product. Utilization of scrap and waste. Methods of labor compensation. Critical analysis of the methods of accounting in representative factories. Factors affecting the cost of production. Layout of complete system of organization, forms, methods of accounting and progress of work for the factory designed in course M. E. 68, Manufacturing Plant Design. Fourth year Mechanical and Chemical Engineering.

Pre-requisites must parallel M. E. 68 for M. E.'s.

53—Steam Turbines. 2 hours. Mr. Parr, Mr. Stone and Associates.

Fundamental Analysis of the Action of Steam Jets and Vanes and Its Application to the Design and Performance of Steam Turbines—Ratio of impulse to reactive force jets, effect of variation of curvature of the buckets, open and closed passages. Flow of steam through nozzles and turbine passages, volume, pressure, temperature, quality, weight, velocity and kinetic energy relations. Centrifugal effect

of steam moving in a curved path. Study of the use of steam in varying types of turbines. Graded pressure turbines, graded velocity turbines, mixed impulse and reaction turbines. Practical turbines belonging to these types, and study of their detailed construction. Efficiency of different types studied by analysis of energy transformation throughout the path of steam and how efficiency is varied by design of blades, passages, nozzles, number of stages, speed, clearance, leakage and mode of regulation. Construction of turbine vanes. Disc and vane friction and critical speed. Governing steam turbines, throttling method, variable admission to one or more stages and periodic admission. Steam consumption of turbines. Book used: *The Steam Turbine*—Stodola. Fourth year Mechanical and Electrical Engineering.

Pre-requisite courses: For Mechanical Engineers, M. E. 17-18, M. E. 31-32; for Electrical Engineers, M. E. 17-18, M. E. 76.

54—Shop Processes, Tools and Time Study. 2 hours. Professor Rautenstrauch, Mr. Miller and Associates.

The Economic Elements in Shop Processes, Time and Power per Unit of Surface Finished or Cut and per Unit of Metal Removed with the Conditions for Most Economic Production—Processes in the shop, functional operation of machine tools and limits of economic production, time of setting, handling, forming and finishing of parts for job and repetition work in quantity. Limits of time, power and cost for finishing surfaces per sq. in. and removing per cu. in. and per lb. by hand and machine operations. Machines for performing specific operations, their functional operation, capacities, adaptability and rate of production. Conditions warranting jigs and fixtures for the production of parts in quantity and for interchangeability. Economy of portable tools, devices and methods of inspection. The selection of economic cutting conditions and analysis of recent experiments. Adaptation of economic cutting speeds to machine tools. Labor-saving devices in the pattern shop, tools and appliances used, capacity and adaptability; built-up patterns, single-piece patterns, metal patterns, comparative cost and life of each; patterns for repetition work, rights and lefts, a line of sizes, interchangeable patterns, jobbing patterns, relative economy of alternative practice. Economic production in the foundry, relative value of various methods of molding large and small parts, core making, venting, pouring and handling the work, managing the cupola. Limits of labor, power and fuel per ton of castings as affected by size and form and fraction chargeable to pattern, molding and cupola and finishing. Processes of forging, hand and machine, conditions warranting power hammers, hydraulic presses, bull-dozers, presses, dies and forming devices for the production of duplicate and standard pieces. Labor and power per lb. of forging as affected by tools, size and form of work. Heating and annealing furnaces, consumption of gas and oil, labor, power and fuel per unit annealed. Distribution of cost of machine production between different processes, power, labor, material and effect of shop or tool capacity factor on fixed charges. Third year Mechanical Engineering.

Pre-requisite courses are M. E. 94S, T. C. Shopwork and M. E. 39.

56—Water Power Installations. 1 hour. Mr. Parr.

Selection and Arrangement of Water Wheels, Governors and Auxiliary Appliances for Different Local Conditions, Efficiency of Wheels and Plants—Characteristic of water flow through turbine guides, noz-

zles and buckets, conditions warranting wheel classification, efficiency of wheels as a function of type, head, speed and part gate operation, effects of different forms of gate on efficiency, relative value of standard patterns and special designs to suit local conditions, limits of standard dynamo speeds on wheel speeds. Water wheel governors regulation. Available head at wheels and division of total loss throughout water conductor system, relation between available water supply, possible output and perfection of development work; draft tubes, stop valves, gates, vacuum and pressure relief stand pipes, relief valves and bye-passes, water racks, anchor and frazil ice. Analysis of typical installations. Water power costs. Text: *Water Power Engineering*—Mead. Fourth year Electrical Engineering.

Pre-requisite course: C. E. 77. Parallel course: M. E. 60.

59—Empiric Design. Mr. THOMAS.

Proportioning of Machine Parts by Empiric Methods and the Production of Shop Drawings and Sketches—Modern practice in making, recording and filing shop drawings of machine details and assemblies, bills of material and listing of standard and special parts. Use of standard conventions and interpretation of shop notes on drawings. Shop sketches and dimensions. Forms of machine parts as indicated by the nature of the resistances to be overcome and the characteristics of the material. Plain, box, and ribbed cast sections, shrinkage stresses and the probability of local weaknesses. Proportions of parts by modern empirical formulas derived from practical considerations. Limiting conditions in the use of empirical formulas. Modern practice in the proportioning of machine elements. Proportions of parts adopted by the Master Car Builders' Association, Master Steam Boiler Makers' Association, United States Government, numerous manufacturing concerns and data appearing of the transactions of the various engineering societies and engineering publications. Design of simple castings from assigned data, dies for forming simple parts in a bull-dozer and the frames and parts of simple machines having given the detailed drawing of the other parts necessary to the determination of the principal dimensions. Second year Mechanical Engineering and third year Chemical Engineering.

The pre-requisite courses are Drafting 1 or 2.

60—Hydraulic Laboratory. Mr. PARR and Mr. THURSTON.

Practical Work on the Flowing of Water for the Determination of Rational Coefficients with Ordinary and Extraordinary Conditions—Flow through simple holes in plate and sort tubes under low heads. Flow through convergent nozzles and needle orifice. Flow through straight pipe, elbows and joints, distribution across the cross section near bends with velocity. Flow through open channels. Flow over weirs. Variation of rectangular, trapezoidal and triangular, sharp versus dull edge, approach contractions, one side, both sides and bottom. Hook gauge measurements. Measurement of quantity flowing by Venturi tube and Pitot tube. Variation of error with type, pressure drop, and size. Loss of heads by sudden enlargement in cross section in pipes running full. Inertia and water shock. Water wheels. Variation of efficiency with speed and head, analysis of losses in nozzles, bucket and friction. Text: *Lecture Notes.* Fourth year Electrical Engineering and third year Mechanical Engineering.

Parallel course: For Mechanical Engineers, C. E. 78. Pre-requisite for Electrical Engineers: C. E. 77.

61—Seminar. 1 hour. Professor LUCKE.

Discussion by students of current topics in mechanical engineering practice, drawn from the Transactions of the American Society of Mechanical Engineers and from selected journals. Papers are assigned for critical analysis and report which are read and discussed in class as in professional society meetings. Fourth year Mechanical Engineering.

62—Refrigeration Machinery. Mr. THURSTON and Mr. OPHULS.

Relative Equipment, Space Occupied, Fuel and Water Consumption per Ton of Refrigeration or of Manufactured Ice for Principal Systems—Physical properties of anhydrous ammonia, carbonic acid, aqua ammonia, sodium and calcium brine solutions. Ammonia compression systems, wet and dry and oil injection systems. Liquid storage, pressure and liquid receiver tanks, pipe and fittings, expansion valves, direct expansion coils. double pipe, submerged and shell brine coolers, insulation of tanks and pipes, brine circulating pumps. Compressors. Ammonia condensers, atmospheric, double pipe and submerged, condenser water cooling towers, ammonia fore-coolers and oil coolers for oil system. Carbonic acid systems, characteristics and quantities compared with anhydrous ammonia. Ammonia absorption systems. Absorber constructions, generator construction. Dense air systems. Air drying. Refrigerating rooms, brewery, meat, general stores, restaurants. Ice making. Can and plate systems, water purification systems, oil separators, steam condensers, reboilers, evaporators, single and multiple effect, skimmers, water storage tank and governors. Quantity of water per ton of ice. quantity of steam condensed from compressor and auxiliaries, available and make-up water. Text: *Compend. of Mechanical Refrigerating*—Siebel. Third year Mechanical Engineering.

Pre-requisite course: M. E. 17. Parallel course: M. E. 18.

63—Hydraulic Laboratory. 1 afternoon. Mr. PARR assisted by Mr. THURSTON.

Same as M. E. 69. Fourth year Civil Engineering.

Parallel course: Hydraulics, C. E. 75.

64—Air Machinery. 2 hours. Professor LUCKE and Mr. O'NEIL.

Structures, Adaptability and Economy of Fans, Air, Gas and Vapor Compressors, Blowing Engines, Jet Blast Apparatus and Important Applications—Convection movement of air; flow of air through orifices, ducts, pipes. Hygrometric conditions of air with temperature and pressure and condensation of moisture in compressed air. Air compressors, types and construction; work of compression, M. E. P. for single and multi stage, cylinder ratios, effects of intercooling. Volumetric efficiency of compressors, real and apparent. Discharge pipe pressure pulsations, air receivers, intercooling receivers. Air end valves, poppet, slide, Corliss and ring valves, suction and delivery, differences in type and diameter and lift. Steam end valve gears and cylinder arrangement. Constant and variable speed compressor valve gear characteristics, pressure and speed controllers and governors. Analysis of complete compressor economy tests. Dry vacuum air pumps. Blowing engines, special forms and sizes of air end valves introduced by cylinders of large diameters for low pressure air. Ammonia and carbonic acid compressors; peculiarities and methods of handling liquid in the vapor; forms and characteristics. Multi-stage centrifugal fans and service. Analysis of efficiency tests for fans and

blowers. Positive blowers. Steam jet blowers and exhausters, thermal efficiency. Application of principles to ventilation and heating, blast furnace practice, compressed air and compressed gas power transmission systems, air lift pumps and air brakes. Third year Mechanical Engineering.

Pre-requisite course: M. E. 17.

66—Elevators and Conveyors. 1 hour. Professor RAUTENSTRAUCH and Mr. MOSS.

Mechanical Handling of Solid Materials by Standard Elevating and Conveying Machinery, Characteristics, Speed, Tonnage and H.P. per Ton, Computations and Adaptability to Special Service—Hand handling of materials, limits, cost and conditions warranting use of machinery. Continuous conveyors, screw, bucket, scrapers, pusher, belt and pneumatic types. Intermittent conveyors; telephers, rope and cable ways, cable cars. Loaders, unloaders, storage facilities. Skips, grab buckets, tips and tipples. Short and long hoists, friction drum hoists and direct connected. Pneumatic and hydraulic elevators for freight. Fixed and travelling cranes. Passenger elevators, rope and plunger types. Safety devices. Automatic weighers of materials; coal and ore storage systems. Excavating machine and dredges. Coal and ore-handling machinery. Railroad terminal and steamship loaders and unloaders. Coke oven chargers and dischargers. Grain handling. Special adaptation to material, such as sand, plaster, glass, cement, broken rock, coal, coke, packages, barrels, corrosive, erosive, sticky, packing, and hot materials. Third year Mechanical Engineering.

Pre-requisite course: M. E. 39.

68—Manufacturing Plant Design. 2 hours and 1 afternoon. Professor RAUTENSTRAUCH, Mr. GOING and Associate.

Methods of Procedure for the Design of a Plant for the Manufacture of an Assigned Product at a Given Rate—Determination of kind and quantity of materials needed, processes by which they may be most economically worked, selection of machinery for each process, determination of the number of each kind of machine required, power necessary to drive. Layout of shops for most direct production. Selection of facilities for handling, storing and shipping on the basis of economy effected. Grouping of pattern and machine shops, foundry, forge and general office; estimate of costs of equipment and installation. Layout of heating, ventilating and lighting systems, power transmission systems and facilities for reduction of fire hazard. Layout of system of management and cost determining system. Fourth year Mechanical Engineering.

Pre-requisite course: E. E. 103; and must be paralleled by M. E. 52.

70—Pumping Machinery. Mr. THURSTON and Mr. HAGUE.

The Mechanics of Moving Liquids and Standard Machinery for Pumping—Water elevators, conditions for high efficiency and limits of use. Displacement, piston and plunger pumps; forms and functions of water pistons and plungers, pump bucket forms and limits of use, volumetric efficiency of water ends. Valves for water end, mechanical, flap, poppet, ball, annular, flat, double beat type and relation, adaptability to fluid, speed and temperature; forms of valve seats, conditions for perfect flow, piston speed and water inertia. Air chambers. Suction limitations of altitude, water temperature and absorbed gases and acceleration. Peculiarities of high pressure work, accumulators. Flywheel pumps, steam end characteristics, relation between steam and

water diameters and displacements. Direct acting pumps, valve motion in single types, full and partial steam throw valves for simple, compound and triple use of steam. Duplex direct acting pumps, structural and operating characteristics. Economy of direct acting simple and multiple expansion pumps. Centrifugal and turbine pumps, forms and operative characteristics. High duty pumping engines, conditions for maximum duty referred to steam and coal; pumping engine tests, methods of conducting and analysis of results obtained. Typical pumping engine installations. Pulsometer pumps. Jet apparatus, injectors, ejectors and eductors, construction and duty as pumps. Water relief valves, pressure and float pump governors. Third year Mechanical, Civil and Chemical Engineering.

Pre-requisite course: M. E. **17.** Parallel C. E. **78.**

72—**Gas Power Machinery.** 2 hours and 1 afternoon. Professor LUCKE.

Short course adapted from M. E. 22. Fourth year Electrical and Metallurgical Engineering.

Pre-requisite course: M. E. **17.**

74—**Gas Power Machinery.** 2 hours.

Same as 72 except the time. Fourth year Mining Engineering.

Pre-requisite course: M. E. **17.**

76—**Experimental Engineering.** 1 hour and 1 afternoon. Mr. PARR and Mr. THURSTON.

Short course adapted from M. E. **31, 32, 33.**

Third year Metallurgical, fourth year Chemical, third year Mining and third year Electrical Engineering.

Pre-requisite for Mining, Chemical, Metallurgical and Electrical Engineers: M. E. **13-14** and M. E. **17.** Parallel for Electrical Engineers: M. E. **18.**

77—**Experimental Engineering.** 1 hour and 1 afternoon. Mr. PARR and Mr. THURSTON.

Third year Civil, fourth year Chemical and fourth year Electrical Engineering.

Short course adapted from M. E. **31, 32, 33.**

Pre-requisite for Civil and Chemical Engineers: M. E. **13-14** and M. E. **17;** for Electrical Engineers, M. E. **17-18** and M. E. **76.**

78—**Kinematics.** 1 afternoon. Mr. THOMAS.

Short course adopted from M. E. 36. Third year Civil Engineering.

Pre-requisite: Math. **3-4.**

82—**Heating and Ventilation.** 3 hours. Professor LUCKE.

Principles of Heat Generation Transfer and Air Movement Applied to Warming and Ventilation of Buildings—Quantities of air needed for proper ventilation, amount of heat necessary to maintain temperatures against conduction, radiation and air change losses. Heating surface and coefficients of heat transfer, grate surface, pipe and duct sizes for high and low pressure steam heating, direct and indirect, hot water and hot air systems. Air tempering, cleaning, drying, humidifying. Pipe and duct layouts. Fan computations. Exhaust steam systems, vacuum circulation. Reducing valves, air valves, water expansion tanks, thermostats, thermostatic regulation systems and important details. Efficiencies of various systems and analysis of existing installations. Fourth year Sanitary Engineering.

94S—Manufacturing Plant Summer Work. Professor RAUTENSTRAUCH.

Practical Work and Directed Study in the Shops and Drafting Rooms of Representative Manufacturing Establishments with Report—Each student is provided with a printed copy of the things to be studied and reported on in detail, of which the following is a general summary:

Machine Shop. Functional operation, characteristics and powering of machine tools, capacities, layout of shop, size of shafting, belting and motors for independent and group drive. Range of cutting speeds, feeds, depth of cut. Shape and size of tools used. Report on specific observations on time of setting work, time of forming and finishing, number of pieces turned out per hour. Facilities for handling work at the machine. Facilities for producing pieces in quantity. Hand processes for finishing and tools used.

Pattern Shop. Materials of which patterns are made and methods of treating. Machine tools used in the pattern shop arrangement, capacities, adaptability, handling and storing of material and finished product.

Foundry and Forge. Description of hand and machine tools and appliances used in the foundry and forge. Compositing and treatment of foundry sands. Methods of molding. Time involved. Methods of powering, venting and chilling, cooling and finishing, handling the cupola. Composition of the charges and mixtures, temperatures, pressures, time required to charge, to melt, to pour, cool and clean. Appliances in the forge shop. Operation of power hammers, bull-dozers, shears, heating and annealing furnaces and hand processes of forging. Time involved in production.

Drafting Room. Standards and conventions used. Filing and marking of drawings and recording of patterns. Bills of material—parts to be made—standard parts in stock.

General Management and Organization. Methods of recording time of workmen and their time distribution over on different jobs. Paying of men, methods, rates, forms and records used. Drawing of materials used from storeroom and charging to orders.

Pre-requisite course is second year shop work.

96S—Power Plant Summer Work. Professor LUCKE.

Report based on not less than six weeks' practical work in an Operating Power Plant, including the Output, Load Conditions, Labor and Material for Operation and Maintenance, Operating Cost per Unit and the Essential Dimensional Relations between the Various Units and Auxiliaries Producing this Result—This work is done entirely by the student in the field, his only assistance being the blank report form which is put in his hands after a brief lecture on leaving the University for the vacation. Third year Mechanical Engineering.

Pre-requisite courses: M. E. 17-18, 31-32.

Graduate Courses

201-202—Research. Professors LUCKE and RAUTENSTRAUCH.

Special problems and original investigations in advanced mechanical engineering with conferences, laboratory work, and design as required.

Pre-requisite: All courses offered in department of Mechanical Engineering.

203-204—Mechanics of the Steam Turbine. Professor LUCKE.

Advanced course based on M. E. 53, using Stodola, *The Steam Turbine* as a text, consisting principally of problem solution.

205-206—Vibration in Machines. Professor RAUTENSTRAUCH.

Forces due to rotation of masses irregularly distributed in one plane; balancing of rotating systems by one or more new masses; rotation in several planes rotating couples; inertia effects of reciprocating masses; systems with both rotating and reciprocating and irregular moving masses; vibration of supports and framing; vibration of building; synchronism of period of building with period of machine.

207-208—Advanced Machine Design. Professor RAUTENSTRAUCH.

Design of special machinery for specific processes, automatic machinery for rapid production of parts, and machinery for improving existing processes of manufacture.

METALLURGY

101—General Metallurgy. 3 hours first half of term. Dr. KERN.

An introduction to general metallurgy; consideration of the methods. Object of the metallurgist, and application of physics and chemistry to the extraction, and to the treatment of the commoner metals. General classification of processes. Classification of fuels, and the selection of the most suitable fuels for certain purposes. The calorific value, and the temperature of combustion, of fuels. Preparation of charcoal and coke, and the recovery and utilization of their by-products. Artificial gaseous fuels, their preparation and metallurgical utilization. Properties of gases, and the metallurgical application of the laws of gases. Classification of furnaces, and the types of furnaces for specific purposes. Refractory materials, and their use in the construction of furnaces. Transmission of heat and the thermal efficiency of furnaces. Calculation of height, sectional areas, capacity and drafts of chimneys. Fuel economizers, and their application to metallurgical furnaces. High temperature measurements.

Third year students in Metallurgical Engineering. Fourth year students, Mining Engineering, Chemical Engineering and Chemistry.

Pre-requisite: Chemistry 3-4 and Physics 3-4.

111—Metallurgy of Copper. 3 hours, second half of term. Dr. KERN.

The production of copper, its uses, and consumption. Properties of copper and its alloys. The ores of copper, and distribution. Characteristics of ores of the principal districts. Sampling, and preparation of copper ores for treatment, and cost of different methods of sampling. General outline of the metallurgy of copper. Roasting of copper ores; purposes; chemistry; and methods of roasting. The advantages, disadvantages, and comparative cost of roasting processes. Introduction to smelting copper ores in reverberatory, and in blast furnaces. Composition, physical properties, and characteristics of furnace products: blister copper, black-copper, mattes, speiss, slag, and flue-dust. Smelting in reverberatory furnaces; construction of reverberatory smelting furnaces, their capacity and efficiency. Calculation of reverberatory furnace charges. Converting of copper matte in reverberatory furnaces. Smelting of copper ores in blast-furnaces. Calculation of blast-furnace charges. "Pyrite" or "Raw Ore" Smelting. Converting of copper matte by the Mahnés process. Apparatus required for converting copper matte. Refining of blister copper, black-copper, and cement-copper. Smelting of typical copper ores, producing ingot copper; the handling, and the disposition of the furnace products; cost of treatment.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry.

Pre-requisite: Metallurgy 101.

118—Metallurgy of Copper. 1 hour. Dr. KERN.

Advanced Course. Treatment of low-grade ores, and of copper-silver ores by leaching. Recovery of copper from mine-water. Utilization of furnace-gas for the production of sulphuric acid. Treatment of copper-nickel ores. Metallurgical calculations of roasting operations. Application of thermo-chemistry to roasting and smelting, and to calculations of furnace efficiencies. Purchasing of copper ores and fluxes.

Fourth year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 111.

122—Metallurgy of Lead, Silver, Gold and Zinc. 3 hours. Professor WALKER.

Metallurgy of Lead—Properties of lead, its compounds and alloys. Classification of ores. Production and uses of lead. Outline of the metallurgical treatment of lead ores. Smelting in the reverberatory furnaces; in the ore-hearth. Blast furnace practice for smelting lead ores. Roasting in hand and mechanical furnaces. Various pot-roasting processes and sintering machines. Smelting operations; construction of furnaces; calculation of charge; disposition, handling and treatment of by-products. Desilverization of lead bullion. Influence of impurities and elimination of same. Cupellation of rich lead alloys and ores. Treatment of Dore.

Metallurgy of Silver. Its properties, compounds, alloys, etc. Direct amalgamation of silver ores. Hydro-metallurgical processes for treatment of silver ores: Ziervogel, Patera, etc.

Metallurgy of Gold. Properties, etc. Amalgamation of gold ores. Chlorination processes. Cyaniding of gold ores; laboratory tests, and chemistry of the process; modern practice, description of existing plants. Refining and parting of gold and silver bullion.

Metallurgy of Zinc. Properties, ores, etc. Calcination and roasting of zinc ores. Retorting furnaces. Manufacture of retorts; retorting practice and chemistry of same. Refining of zinc.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry.

Pre-requisite: Metallurgy 111.

128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. 1 hour. Professor WALKER.

Advanced Course. Methods of receiving and sampling different classes of ore. Purchasing of ore of varying compositions. General construction of furnaces, and design of smelting plants. Organization of smelting plants; metallurgical bookkeeping, cost sheets, etc.

Fourth year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 122.

131—Metallurgy of Iron and Steel. 2 hours, first half of term. Professor CAMPBELL.

Manufacture of iron and steel. Blast furnace. Puddling. Cementation. Crucible process. Bessemer process. Open hearth process.

Statistics. Iron and steel casting. Effect of heat treatment. Effect of mechanical treatment. Malleable cast iron. Standard specifications. Constitution of iron and steel. Relation to physical properties. Change of structure with heat and mechanical treatment. Alloy steels. Corrosion.

Fourth year students in Mining and Metallurgical Engineering and Chemistry. Third year students in Chemical Engineering.

Pre-requisite: Chemistry 3-4 and Physics 3-4. Pre-requisite or parallel: Metallurgy 101.

134—Metallurgy of Iron and Steel. 2 hours. Professors WALKER and CAMPBELL.

Introduction, literature, scheme of iron and steel manufacture. Definitions: iron, steel, cast iron, etc. Relations of carbon and iron. Development of the industry. The blast furnace, iron ores, fuels, fluxes, smelting practice, products. Processes for purification of pig iron. Manufacture of wrought iron and crucible steel. Puddling, charcoal hearths, fineries. Cementation, blister steel. Crucible process. Bessemer process, acid and basic. Siemens-Martin or Open Hearth process, acid and basic: fuels and regeneration. Defects in ingots and other castings. Iron and steel founding. Mechanical treatment of steel, forging, rolling. Heat treatment of steel. Heat treatment of cast iron. Malleable cast iron, cupola and air furnace. Alloy steels; nickel; vanadium; manganese; chrome; tungsten, etc. Self-hardening, high-speed steels.

Practical metallography of iron and steel. Macroscopic examination Microscopic examination of wrought iron, pipe steel, low carbon and structural steel. Shafting, etc. Medium and high carbon, rails and tires. Tool steels. Cast irons. Comparison of good with bad material. Relation between structure and properties. Corrosion. Standard specifications. Electrometallurgy of iron and steel.

Second year students in Civil, Electrical, and Mechanical Engineering.

Pre-requisite: Chemistry 3-4 and Physics 3-4.

138—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Advanced Course. A detailed study of the constitution of iron and steel and the effects of heat and mechanical treatment upon the constituents. Discussion of the various processes of manufacture of iron and steel, alloys steels, etc. The iron and steel industry of the United States, Germany, England, and other countries. Standard methods of testing.

Fourth year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 131.

141—Electrometallurgy. 2 hours, second half of term. Dr. KERN.

Theory of the electric current, and its application in the treatment of ores, refining of metals, and production of refractory alloys. Theory of electrolysis; determination of efficiency. The solution pressure series of the metals, and its application in the refining of copper, lead, iron, nickel, antimony, tin, zinc, gold, and silver. Electrolytic refining of copper. Electrolytic refining of lead. Treatment of anode residual. Parting of silver and gold by electrolysis. Refining of gold alloys. Electrolysis of fused electrolytes: production of aluminum; treatment of sulphide ores, etc. Electric furnaces used: for smelting ores, for refining metals, and for manufacture of refractory alloys. Efficiency of electric furnaces; cost of constructing and maintaining.

Fourth year students in Mining and Metallurgical Engineering, and Chemistry. Third year students in Chemical Engineering.

Pre-requisite: Chemistry 3-4 and Physics 3-4.

148—Electrometallurgy. 1 hour conference. Dr. KERN.

Advanced Course. Construction of electrolytic refineries; calculations of current, and power efficiencies. Selection of most suitable electrolyte, and most economical current density. Labor-saving appliances. Electrolytic deposition of copper, lead, zinc, nickel, gold and silver from solutions obtained by leaching their ores. Production of solid deposits, and laws governing the same. Rôle of current density in the electrolysis of aqueous and fused electrolytes, and in the operation of electric furnaces.

Fourth year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 141.

151—Constitution and Properties of Alloys. 2 hours. Professor CAMPBELL.

Pyrometry and freezing point or cooling curves. Various types of curves and their meaning. Examples of the same. Constitution of the various binary alloys. Methods of manufacture of commercial alloys. Ternary alloys. The phase rule. Change of structure in the solid state, pure metals, alloys, bronze, brass, steel. Methods of metallographic research.

Fourth year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 111; Parallel Metallurgy 131.

155-6—Metallography. Iron, Steel and Industrial Alloys. Six lectures and 3 or more afternoons laboratory. Professor CAMPBELL.

Methods of examination. Comparison of good and bad material; wrought iron, low carbon steel, structural steel, rail steel, tool steel, etc. Examination of brasses, bronzes, bearing metals and other industrial alloys. Relation between chemical composition, physical properties and microstructure.

Course for students in Mechanical Engineering, and for special students.

Pre-requisite: Metallurgy 131 or 134.

158—Advanced Course on Constitution and Property of Alloys. 1 hour. Professor CAMPBELL.

Pre-requisite: Metallurgy 151.

62S—Summer Course in Non-Ferrous Metallurgy. Dr. KERN.

For description see page 37. 1 week field work at metallurgical plants during the summer.

Instruction for this field work will be given in five one-hour conferences during the last week in April.

Third year students in Mining Engineering.

64S—Summer Course in Ferrous Metallurgy. Professor CAMPBELL.

For description see page 37. Third year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 101.

66S—Summer Course in Non-Ferrous Metallurgy. Dr. KERN.

For description see page 37. Third year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 122.

72—Metallurgical Laboratory. 10 consecutive afternoons, second term. Professor CAMPBELL and Dr. KERN.

Calibration of Le Chatelier pyrometer. Cyaniding and chlorination of gold ores. Roasting of copper matte, and use of pyrometer. Desilverizing of base bullion by Parke's process. Microscopic metallography. Thermal treatment of steels.

Fourth year students in Mining and Chemical Engineering.

Pre-requisite: Metallurgy 111. Parallel: Metallurgy 122.

78—Thesis.

Required of students in Metallurgical Engineering.

Pre-requisite: Metallurgy 122, 131, 141, 171.

171—Metallurgical Laboratory. 2 afternoons. Professor CAMPBELL and Dr. KERN.

Calibration and comparison of thermo-electric, optical and radiation pyrometers. Determination of the calorific power of fuels by the Mahler-Berthelot calorimeter. Microscopic study of metals and alloys. Thermal and mechanical treatment of steels and cast iron. Roasting of copper matte, and use of pyrometer. Production of blister copper by the reaction process. Refining of blister copper. Desilverization of base bullion by Parke's process. Cyaniding of gold and silver ores. Chlorination of gold ores. Electrolytic refining of copper and lead bullion. Fusibility of slags and refractory materials.

Third year students in Metallurgical Engineering.

Parallel: Metallurgy 101 and 111.

173-174—Metallurgical Laboratory.

Special work along the lines indicated under the head of Metallurgy 201-202. This work is intermediate between that of Metallurgy 171 and 201-202 and is designed for those desiring to take an advanced metallurgical laboratory course without confining themselves to special research work.

175—Metallurgical Investigation. 1 hour conferences. Professors WALKER and CAMPBELL.

Fourth year Metallurgical Engineers.

Pre-requisite: Metallurgy 122.
Pre-requisite or parallel: 131, 141.

177—Metallurgical Plant Construction. Professors WALKER and CAMPBELL and Dr. KERN.

General design of metallurgical plants and problems entering into the construction of same.

Special work is assigned to each student, which is carried on under direct and constant supervision in the drafting room and laboratories. The experience gained in visits to metallurgical plants is brought into practical use.

Fourth year Metallurgical Engineers.

Pre-requisite: Drafting 3-4, 7-8; Civil Engineering 53; Metallurgy 122, 64S and 66S.

Graduate Courses

Special courses, consisting of original research, will be arranged for advanced students according to their individual needs and abilities. Most of these researches will consist of work in the departmental laboratories, but others will consist of study, and still others of work in industrial establishments.

The amount of time required for these courses is governed by the rule that a course or courses should be taken for one year and occupy 12 hours a week (preparation included) if taken as a major subject, and 6 hours a week if taken as a minor subject for a degree of A.M. For the degree of Ph.D. at least two years, graduate work and special investigation, is required.

The following list shows what subjects are suited to these courses:

201-202 (*a*)—Advanced work on some problem in general metallurgy, as for example:

In Calorimetry: Determination of the calorific power of fuels, or testing some law in calorimetry;

In Pyrometry: Determination of the temperatures of metallurgical and other industrial high-temperature operations;

On Refractory Materials: Their resistance to heat and corrosion; their tendency to slack; their contraction and expansion, etc.;

On Slags: The formation points, melting points, flowing points, and their density and viscosity when molten;

(*b*)—In the Metallurgy of Copper:

The chemistry of roasting processes, such as the elimination of arsenic and sulphur; chloridizing and sulphate roasting, etc.

The reactions of smelting processes;

Wet methods of extraction;

(*c*)—In the Metallurgy of Lead, Silver, Gold, etc.:

The pot-roasting of sulphides, and others mentioned above under (*b*);

(*d*)—In the Metallurgy of Iron and Steel:

The chemistry of the blast furnace;

The chemistry of the basic dephosphorizing processes;

The heat treatment of iron and steel: its physical, crystallographic and chemical effect;

The components and constitution of iron, steel, and alloy steels;

(*e*)—In Electro-metallurgy: Testing electro-metallurgical principles, refining, extraction and depositing process;

(*f*)—On Alloys: The constitution and properties of alloys, embracing a microscopic, pyrometric and mechanical or physical examination with a correlation of the results;

(*g*)—In Metallography: Metallography of iron, steel, industrial alloys or metallurgical products, as mattes, slags, etc.

Pre-requisite for 201-202: Metallurgy 122, 131, 141 and 171, or equivalent.

MINERALOGY

1—Descriptive and Determinative Mineralogy. 6 hours lectures. 9 hours laboratory. Professors Moses and Luquer and Assistants.

The elements of crystallography. The blowpipe analysis of ores and other substances. The study of the important minerals, the purpose being: 1st. Sight recognition of average specimens of all common or economically important species; 2d. Rapid determination of the less characteristic specimens by simple tests; 3d. Familiarity with economic characters.

Pre-requisite: Entrance requirements in Chemistry and Physics.
Prescribed course for students in Mining.

5—The Minerals of Building Stones. 2 hours lectures and 1 afternoon laboratory. Professor Luquer and Assistant.

Study of common species, their properties, methods of determination, and their economic effect on building stones.

Prescribed for students in the course of Civil Engineering.

6—Optical Mineralogy. In sections, 2 afternoons per week for first seven weeks of term. Professor LUQUER and Assistant.

Principles, apparatus, and distinguishing characters of minerals in thin sections. Consists principally in the determination of minerals in rock sections by the aid of the polarizing microscope. Supplements Courses 5 and 1 and is preliminary to Geology 4 (petrography).

Pre-requisite: Course 5, or part of Course 1, or its equivalent.
Prescribed for students in Mining.

7—Descriptive and Determinative Mineralogy. 6 hours lectures, 6 hours laboratory.

Modification of Mineralogy 1. Lectures identical, laboratory work condensed.

Prescribed course for students in Metallurgy.

15-16—Mineralogy. 3 hours laboratory. Professor MOSES and Assistant.

Sight recognition and determination of minerals important in the chemical industries.

Pre-requisite: Chemistry A and Physics A.

Prescribed for students in Chemistry and Chemical Engineering.

MINING

Undergraduate Courses

51—Excavation and Tunneling. 3 hours, first half third year. Professor PEELE.

Excavation of earth: tools and methods employed, support of excavations, special methods for quicksand and other water-bearing material; steam shovels and other mechanical excavators; handling and transportation of excavated material; comparative costs. Explosives: black powder, nitro-glycerine and its compounds, and other high explosives; their composition, manufacture, and use. Excavation of rock: methods of drilling and blasting, mammoth blasts, submarine blasting. Railroad tunnels: methods of driving and timbering; handling and transportation of excavated material; drainage and ventilation; lining of tunnels, submarine tunnels. Mine tunnels; examples from practice; sizes, details of driving, timbering, rates of advance and costs.

Required of students in the course of Mining Engineering.
Pre-requisite: Entrance requirements in Mathematics, Chemistry, and Physics.

52—Boring and Shaft Sinking. 2 hours, second half third year. Professor PEELE.

Boring: methods and appliances for small depths and for deep boring; rod boring and cable tool or oil-well method; boring with core drills, for prospecting and other purposes; survey of bore-holes. Shaft sinking: methods and tools employed in soft material and in rock; sinking linings or drop-shafts, freezing and other special methods of

sinking in soft water-bearing formations; drainage of shafts; handling and hoisting of excavated material. Shaft timbering, walling, tubbing, and other forms of lining. Costs of shaft sinking.

Required of students in the course of Mining Engineering.

Pre-requisite: Mining 51.

53—Excavation, Tunneling, Boring and Shaft Sinking. 3 hours, first half second year. Mr. Judd.

A condensation of courses 51 and 52, in which attention is given only to those operations that are of special interest to the civil engineer. Excavation and transport of earth for structural purposes and railroad grading; steam shovels and dredges. Explosives. Excavation of rock; methods of drilling and blasting; submarine blasting; railroad tunnels; quarrying; testing for foundations in earth, rock and watery material; well drilling; shaft sinking by usual and special methods.

Required of students in the course of Civil Engineering.

Pre-requisite: Entrance requirements in Mathematics, Chemistry and Physics.

54—Exploration, Development, and Methods of Working. 3 hours, second half third year. Professor Munroe.

Mineral deposits, characteristics of beds, masses, veins, and other deposits, and the irregularities and disturbances to which they are subject, as affecting the work of exploration and mining. Examination and survey of mineral properties; relation of topography to geological structure; construction of maps and sections; and tracing of probable outcrops as a guide to exploration. Prospecting by ditches, pits, and deep boring. Development; choice of methods; location of openings. Working of deposits and support of excavations; theoretical considerations, methods of breaking ground in coal and metal mining, and support of mine excavations by pillars of mineral, by timbering, by masonry, and by rock filling; methods of working applicable to deposits of different thickness, inclination, and character. Coal mining; vein mining; working of thick deposits and soft-ore bodies. Salt mining. Surface workings. Hydraulic mining and gold dredging.

Required of students in the courses of Mining and Metallurgical Engineering.

Pre-requisite: Geology 5-6. Pre-requisites or parallels: Geology 105-106, Mining 51 and 52.

Accepted together with Mining 81 and 82, or with Mining 56 and 91, as a minor for the degree of A.M.

56—Mine Engineering. 3 hours, fourth year. Professor Munroe.

Ventilation; air of mines; mine gases; methods of ventilation; control and measurement of air currents. Drainage: sources of mine waters; methods for the control and raising of water; dams; drainage levels. Water supply. Surface handling and transportation; arrangements for loading and unloading cars and vessels, and for storing of minerals. Mineral railroads. Common roads. Accidents to men in shafts, levels and working places; fire-damp and dust explosions; mine fires; inundations; rescue and relief of men. Mine surveying, mine maps and models. Examination, sampling and valuation of mines

Required of students in the course of Mining Engineering.

Pre-requisites or parallels: Mining 54 and 71-72, Civil Engineering 76 and 28.

Accepted together with Mining 54 and 91, as a minor for the degree of A.M.

71-72—Mine Plant. 3 hours, fourth year. Professor Peele.

Description and critical discussion of the machinery and appliances

employed in the equipment of mines; design, erection and care of plant. Hoisting: engines, drums, wire rope, skips and cages, head-frames; calculation of power required and methods of equalizing the load on the engine; shaft-sinking plant, over-winding. Drainage: buckets, tanks and hand-pumps; Cornish and direct-acting underground pumps; operation of pumps by electricity, compressed air, and hydraulic power. Centrifugal pumps. Ventilation: underground furnaces, positive blowers, and centrifugal fans; theory and efficiencies of fans. Air compressors: simple and compound (stage) compression; methods of dealing with heat of compression; conveyance of compressed air in pipes; reheating; operation of machinery by compressed air; efficiencies. Machine drills; coal-mining machines or coal-cutters. Handling mineral in working places. Mine cars; arrangement and construction of tracks. Underground haulage; hand tramming; mule haulage; gravity roads; steam, compressed-air, and electric locomotives; rope haulage; efficiencies; comparison of systems of haulage

Required of students in the course of Mining Engineering.

Pre-requisite: Mining 51, 52 and 54, and Mechanical Engineering 13-14. Accepted together with Mining 73 and 75, as a minor for the degree of A.M.

73—Mine Constructions. 1 hour, fourth year. Professor Peele.

Building-stones; bricks; limes; cements and concretes. Foundations in various soils; retaining walls; masonry and timber construction, with special reference to mine work; mine buildings; trestles; ore-bins

Required of students in the courses of Mining and Metallurgical Engineering.

Accepted together with Mining 71-72 and 75, or with Mining 81, 82 and 75, as a minor for the degree of A.M.

75—Design of Mine Plant. 4 afternoons, fourth year. Professors Peele and Kurtz and Mr. Judd.

The students are assigned problems in the design and construction of mine plant, in connection with the development of a mine. This work supplements the lectures on the design of mining machinery, involving reading and study, and the preparation of working drawings, covering certain portions of the plant, together with bills of material, specifications, and estimates. As these drawings are intended to accompany and illustrate in part the graduating theses or projects, the designs are made in accordance with the subjects and conditions therein assigned. The work is done under constant supervision and advice in the draughting-room.

Required of students in the course of Mining Engineering.

Pre-requisite: Drafting 3-4, 7-8, Civil Engineering 53. Parallel: Mining 71-72.

Accepted together with Mining 71-72 and 73, or with Mining 81, 82 and 73, as a minor for the degree of A.M.

77-78—Graduating Thesis or Project. Professor Peele (see page 37).

Required of students in the course of Mining Engineering.

Pre-requisites or parallel: All the required courses in Mining.

80—Mill Constructions. 1 hour, fourth year. Professor Kurtz.

Installation and operation of mechanical power transmission and auxiliary machinery in works for the mechanical treatment of minerals. Dealing with shafting, bearings, pulleys, belting, rope drives, gearing, etc.

Pre-requisite: Mechanical Engineering 13-14.

81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. 4 hours, fourth year. Professor MUNROE.

The general principles and theory of dressing; preliminary operations; hand dressing; cleansing; crushing; jigging with and without preliminary sizing; slime concentration; magnetic and electro-static separation; oil and flotation processes; milling of gold and silver ores; descriptions of typical dressing works and coal-washing plants in this country and abroad.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisites: Mineralogy 1-2, Physics 3-4. Pre-requisite or parallel: Mechanics 102.

Accepted together with Mining 54 and 82, or with Mining 82, 73 and 75 as a minor for the degree of A.M.

82—Ore-dressing Laboratory. Afternoon work for three weeks, fourth year. Professors MUNROE and KURTZ and Mr. JUDD.

Mechanical testing of ores by laboratory methods; working tests with simple apparatus; adjustment and operation of concentrating machines.

Required of students in the courses of Mining and Metallurgical Engineering.

Pre-requisite or parallel: Mining 81.

Accepted together with Mining 54 and 81, or with Mining 81, 73 and 75, as a minor for the degree of A.M.

91—Mine Administration. 2 hours, fourth year. Professors MUNROE and KURTZ.

Administration, organization, and business management, mine accounts, and cost sheets. Required of students in the courses of Mining and Metallurgical Engineering.

Pre-requisite: Mining 54. Parallel: Mining 56.

Accepted together with Mining 54 and 56, as a minor for the degree of A.M.

94—Mining Law. 2 hours, fourth year. Professor KURTZ.

General principles of real estate law. Historical review of mining laws of various countries. Federal laws, concerning locations on public lands of the United States. State and territorial mining laws.

Pre-requisite; Civil Engineering 27, Mining 54.

95—Mining Conference. 1 hour. Mr. JUDD.

(Optional.) Reading and discussion of papers by the students, on mining practice and based on data accumulated in the course of the summer work in mining.

Summer Courses

58—Summer Class in Mine Surveying is held in June, at a mine in a near locality, and lasts one week. Professors MUNROE and KURTZ and Mr. JUDD.

59—The Summer Courses in Practical Mining. Professors PEELE and KURTZ and Mr. JUDD.

Held in June and July, at some mine or mines selected for the pur-

pose, in the vacation between the third and fourth years, and lasts six to eight weeks (for details see pages 29-30).

Pre-requisites or parallels: Mining **51**, **52** and **54**, Civil Engineering **15**, **27** and **28**, Mechanical Engineering **13** and Geology **105-106**.

Graduate Courses

Special courses, consisting of personal instruction, reading and experimental investigation, will be arranged for advanced students according to their individual needs and ability. These investigations will be made at mines and dressing works either in connection with the Summer class or elsewhere as assigned, with additional work, as required, in the library and in the laboratories of the department. These courses vary in difficulty and in the amount of time necessary, according as the student is a candidate for the degree of A.M. or Ph.D., and according as he pursues mining as a major or a minor subject. The time required is governed by the rule that a course or courses should occupy about 18 hours (outside reading and study included) per week if taken as a major subject, and about 9 hours per week if taken as a minor subject. Any of the following may be offered as a minor for the degree of A.M. by students who have had the appropriate prerequisites:

101-102—**Mining and Ore Dressing.** Mining **54**, **81** and **82**. 4 hours, with laboratory work and reading as required.

103-104—**Mining Engineering.** Mining **54**, **56** and **91**. 4 hours lectures and reading as required.

105-106—**Design of Mine Plant.** Mining **71-72**, **73** and **75**. 3 hours and 5 afternoons drafting-room work.

107-108—**Design of Ore-dressing Works.** Mining **80**, **81**, **82**, **73** and **75**, with 1 hour conference additional first half-year. 3 hours and 5 afternoons laboratory and drafting-room work.

109-110—**Mining.** All the undergraduate courses in the Department of Mining.

Under the regulations for the degrees of A.M. and Ph.D. the following courses may be offered by graduate students who have had all the undergraduate courses in mining or their equivalent.

201-202—**Methods of Mining.** Critical study of methods used in some mining region, or for a certain class of deposits; output per man, amount of timber and explosive required, and other details affecting cost. Study of conditions as determining choice of method. Determination of loss of mineral in mining. Accidents to men.

203-204—**Mining Plant.** Critical study of rock drilling, or coal cutting, or hoisting, or haulage, or ventilating plant at some mine or mines. Determination of efficiency and conditions affecting same.

205-206—**Deep Mining.** Study of problems of deep mining, vertical versus inclined shafts, hoisting and pumping from great depths, temperature and ventilation, efficiency of labor, rock pressure as affecting methods of mining and timbering.

207-208—Ore Dressing. Critical study of some detail of the ordinary dressing methods, crushing, or screening, or classification, or jigging, or slime treatment, or dry concentration, or magnetic separation, or milling of gold or silver ores, or mechanical preparation of coal. Determination of efficiency, and of conditions essential to success.

209-210—Examination of a Coal-washing Plant, or of an Ore-dressing Plant. 4 to 6 weeks' work in the mill and in the laboratory, with conferences.

211—Examination of a Mineral Property, or a Mine. 4 to 6 weeks devoted to field and underground work in the summer school of practical mining, with conferences at convenience of professor.

213-214—Economic Studies in Mining. Study of existing conditions affecting the production and cost of some mineral or metal, as, for example, anthracite coal, copper, or gold.

PHYSICAL EDUCATION

A1-A2—Physical Education. 7 lectures on personal hygiene. During the remainder of the year 2 hours a week of athletics and elementary graded gymnastic exercises. Dr. SKARSTROM.

In sections.

B1-B2—Physical Education. 7 lectures on sanitation and personal hygiene. During the remainder of the year 2 hours a week of athletics and graded gymnastic exercises. Professor MEYLAN and Assistants.

In sections.

PHYSICS AND MECHANICS

Mechanics 1—Elementary Mechanics for Engineering Students. 2 hours a week during the first term. Professors BURNSIDE and

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This course is required of all first year students in Engineering, and consists of recitations and problem work. A text-book is used which follows the algebraic method of analysis rather than the graphical, and which does not involve a knowledge of Calculus. Most of the time is devoted to Statics, and particular attention is paid to the development of fundamental principles by constant appeal to experience. The solution of a large number of numerical problems is required, and considerable drill is given in the use of the English engineer's system of units,

Physics 3-4—Elementary Mechanics and General Physics. Professors WENDELL, PEGRAM, DAVIS, Dr. WEBB, Mr. FARWELL, Mr. SEVERINGHAUS.

Physics 3, five hours a week during first term.

Physics 4, five hours a week during second term.

This course is required of all first year students in Engineering and consists of lectures and recitations. Physics 3 treats the subjects of Elementary Mechanics, Wave Motion and Sound, three lectures and two recitations each week. Physics 4 treats the subjects of Light, Heat, and introductory Electricity and Magnetism, three lectures and two recitations each week.

Physics 5—Electricity, continued from Physics 4. 2 hours a week. Professor WENDELL.

Pre-requisite: Physics 4.

Physics 43-44—Intermediate Laboratory Course. 3 consecutive hours of laboratory work twice a week for one half-year; given each half-year. Professor WENDELL, Dr. MORSE, Mr. FARWELL, Mr. SEVERINGHAUS, Mr. ST. JOHN.

This course consists of quantitative experiments, reports, and individual instruction in the laboratory, and is designed to familiarize the student with the applications of the fundamental principles of physical measurements, methods of computation and the determination of the precision of results.

Pre-requisite: Physics 3-4.

Physics 105—Physical Measurements. 2 hours. Professor HALLOCK.

Pre-requisite: Physics 3-4.

Critical discussion of physical measurements and computations.

Mechanics 102—Analytical Mechanics. 5 hours a week. Professors BURNSIDE, PEGRAM and ———

A course in the fundamental principles of the science of Mechanics treated with especial reference to the requirements of engineers. The unity and universality of the science is emphasized and the limitations of the treatment are carefully noted. Maurer's *Technical Mechanics* is used as a text and may be supplemented by lectures, notes and extra problems. The class is divided into small sections, so that the daily work consists of recitations, rather than lectures, with frequent written and oral quizzes, and the solution of many numerical problems taken from actual engineering work.

The first part of the term is devoted to Statics, the graphic and algebraic methods of analysis being developed side by side. Thus the student is able to solve the same problem by either method, or use one solution as a check upon the other. The treatment deals with the properties of forces as vector quantities, equivalence of force systems, composition and resolution of forces, theory of couples, and applications to many problems.

The theory of centroids and centers of gravity is developed both with and without the aid of the Calculus. The treatment of second moments involves the discussion of moments of inertia of areas, volumes and masses, products of inertia, principal axes and principal moments of inertia.

In kinematics and kinetics, the question of units and dimensions is considered of essential importance, and receives attention accordingly.

Under kinematics are treated the general vector properties of displacement, velocity and acceleration; rectilinear and curvilinear motion of a particle, important special motions; the graphical interpretation of position, displacement, velocity, acceleration and time relations; and the motion of a rigid body in translation, rotation, and any plane motion.

Under kinetics are considered the laws of motion, kinetics of a particle, force, mass, and centrifugal force; kinetics of a system of particles, D'Alembert's principle applied to translation and rotation of rigid bodies, motion of the mass center of any system of particles; kinetic reactions, hinge reactions, balancing of rotating bodies; work and energy, work diagrams, kinetic and potential energy, and applications to train resistance, friction brakes, and efficiency of machines; impulse and momentum, and applications.

Pre-requisite: Physics 3-4, Mechanics 1, and Mathematics 5.

Mechanics 101—Analytical Mechanics. The same course as Mechanics 102, but given in the first term.

Mechanics 105—Thermodynamics. 2 hours. Professor WILLS.

An idea of the nature of the course may be obtained from the following topical headings: The nature of heat; thermometry; calorimetry; heat and work diagrams; the First Law; applications to gases, perfect and actual; the work of Carnot; the Second Law; the Kelvin absolute scale of temperature; the combination of the two laws; application to the problem of change of state; the properties of saturated and superheated steam; theory of the "plug experiment"; the flow of fluids from orifices.

Pre-requisite: Mechanics 102.

Mechanics 107-108—Theory of Electricity and Magnetism. 2 hours first half-year, 3 hours second half-year. Professor WILLS.

The fundamental principles of electricity and magnetism are developed and discussed with particular reference to the bearing which they have in relation to the science of electrical engineering. The course concludes with an introduction into the theory of alternating currents.

Pre-requisite: Mechanics 102.

Mechanics 109—Theory of Alternators and Transformers. 4 hours. Professor PUPIN.

Pre-requisite: Mechanics 107-108.

Mechanics 110—Theory of Variable Currents. 3 hours. Professor PUPIN.

This course treats particularly of the theory of polyphase and high frequency and high potential currents.

Pre-requisite: Mechanics 109.

Mathematical Physics 201—Mechanics. 4 hours. Professor WILLS.

An advanced course on Mechanics developed with special reference to the general methods of d'Alembert, Lagrange, Jacobi and Hamilton.

Mathematical Physics 205—Electricity and Magnetism. 4 hours. Professor PUPIN.

Fundamental phenomena; derivation of Maxwell's Equations; electrostatics; magnetostatics; stationary states; variable states; dynamical phenomena.

Mathematical Physics 206—Theory of Electrical Circuits. 4 hours. Professor PUPIN.

Briefly stated, this course covers advanced electro-mechanics, that is, the mathematical theory of generation and distribution of electrical power by variable electromotive forces. It deals with the theory of construction of alternating current generators, motors, and transformers, and with the theory of the construction of transmission lines for power distribution, telegraphy and telephony; also with wireless signalling.

Mathematical Physics 211-212—Partial Differential Equations of Physics. 4 hours. Professor WILLS.

Laplace's Equation; Poisson's Equation; Equation of Heat Conduction; Telegrapher's Equation; Fourier's Series; Spherical Harmonics; Bessel's Functions.

For other courses in physics and mathematical physics the student is referred to the *Announcement of the Division of Mathematical and Physical Science.*

SHOP WORK

The Work-shops are located in the Macy Manual Arts Building of Teachers College, 120th Street, and may be generally divided into two groups, each having a capacity of from twenty to twenty-four workers. The wood-working course is planned to lead up to pattern-making and foundry-work. The equipment includes benches for joinery and pattern-making with the necessary hand-tools, and speed lathes for wood-turning. The foundry division has facilities for bench and floor molding and for limited work with sweeps. A carpenter shop with saw-benches, planers and tools for profile-sawing is available for working up stock and special appliances.

The second division includes the shops for metal-working. For blacksmith work and forging are twenty Buffalo forges with anvils, tools, and vises. A 30-pound Bradley power-hammer and a 400-pound Billings and Spencer drop-press are used to illustrate and enforce the application of the forge processes to manufacturing.

For machine-tool work a well-equipped shop contains engine-lathes, swinging from twelve to twenty inches, planers, shapers, drill-presses, universal milling machine, universal grinding machines and the subsidiary appliances of the machine shop. A Jones and Lamson flat turret-lathe, and a Warner and Swasey screw machine are used to familiarize the student with modern methods of rapid and economical production, and he is expected to learn their use in manufacturing processes. The tool room is administered according to advanced standards, the attendance record is kept by a Willard & Frick time-keeper's recording clock, and a regular shop organization and atmosphere is aimed at.

1—Wood-turning and Pattern Making. 2 afternoons, first term. Mr. Ross.

Shopwork, demonstrations and shop visits. The construction of typical patterns and core boxes, solid, split and piece, involving the use of bench tools and turning lathe. Mechanical Engineering, Second year.

2—Molding and Foundry Practice. 1 afternoon, second term. Mr. SLEFFEL.

Shopwork, demonstrations and shop visits. Bench molding with type patterns, swept work in green sand and loam and molding in dry sand. Mechanical Engineering. Second year.

10S—Machine Work. Mr. WALSH.

As below. Mechanical Engineering. Section I, three weeks in June; Section II, three weeks in September. Second year.

11—Machine Work. 2 afternoons, first term, third year. Mr. WALSH.

Shopwork, demonstrations and shop visits. Practical work with the lathe, planer, drill, shaper, milling machine, grinder and turret lathe. Assembling, erection and rigger's work. Mechanical Engineering.

12—Forging. 2 afternoons, second term. Mr. SLEFFEL.

Shopwork, demonstrations and shop visits. Management of fire, shaping, drawing, upsetting, swaging, welding, tempering and die-forging. Work on drop and helve hammers. Mechanical Engineering. Second year.

13-14—Machine Work. 1 afternoon. Mr. WALSH.

As above. Electrical Engineering. Second year.

15—Forging and Foundry Practice. 1 afternoon, first term. Mr. SLEFFEL.

As above. Civil Engineering. Second year.

16—Machine Work. 1 afternoon, second term. Mr. WALSH.

As above. Civil Engineering. Second year.

18S—Pattern-making, Forging and Machine Work. Three weeks in June. Mr. WEICK, Mr. SLEFFEL and Mr. WALSH.

As above. Chemical Engineering. Second year.

ZOOLOGY

7—Sanitary Biology. 2 hours and 2 afternoons laboratory a week for 6 weeks. Professor CALKINS and Assistant.

General principles of biology. Biological activity—function, metabolism, symbiosis, etc.; special biology—unicellular animals and plants of drinking waters, causes of trouble, etc.

Pre-requisite: Bacteriology 101.

SCHEDULE OF PREREQUISITES FOR SUBJECTS UNDER THE FACULTY OF APPLIED SCIENCE

Subject	Prerequisite
Astronomy	
105—Geodesy. (For C. E.)	Math. 65 (Differential and Integral Calculus)
106—Geodesy. (For C. E.)	Astron. 105 (Geodesy)
107—Geodesy. (For C. E.)	Astron. 106 (Geodesy)
Bacteriology	
101—Sanitary Bacteriology. (For Sanitary Engineers)	Chem. 92a (Miscroscopy)
Botany	
7—Growth and Character of Timber	
Chemistry	
3-4—General Inorganic	Entrance Chemistry or Chem.A.
7-8—Inorganic	Chem. 21-22 (Elementary Physical Chemistry) Chem. 163-164 (Quantitative Analysis) Chem. 83-84 (Industrial Chemistry) Chem. 91-92 (Chemical Microscopy) Chem. 101-102 (Advanced Inorganic) Chem. 171 (Organic and Sanitary Analysis) Chem. 170 (Assaying) Chem. 183-184 (Industrial Electro-Chemistry)
101-102—Advanced Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
21-22—Elementary Physical Chemistry	Chem. 3-4 (General Inorganic) Phys. 3-4 (Elementary Mechanics and General Physics)
121-122—Physical Chemistry	Chem. 65 (Quantitative Analysis) Phys. 3-4 (Elementary Mechanics and General Physics) Math. 65 (Differential and Integral Calculus)
38—Theoretical Electro-Chemistry	Chem. 65 (Quantitative Analysis, Inorganic) Phys. 3-4 (Elementary Mechanics and General Physics) Math. 65 (Differential and Integral Calculus)
23-24—Physical Chemistry	Chem. 3-4 (General Inorganic)
41-42—Organic, lectures	Chem. 41-42 (Organic) or parallel
43-44—Organic laboratory	Chem. 21-22 (Elementary Physical Chemistry)
141-142—Organic, general	Chem. 161-162 (Quantitative Analysis, Inorganic) Chem. 141-142 (Organic)
143-144—Organic, conferences	Chem. 41-42 (Organic)
150—Advanced Organic. (For Chem. E.)	
61 or 62—Qualitative Analysis	Entrance Chemistry or Chem.A.
Parallel Chem. 3-4 (General Inorganic)	
65—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
66—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
161-162—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
163-164—Quantitative Analysis	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)

Subject	Prerequisite
Chemistry (*Continued*):	
167-168—Advanced Inorganic Analysis	Chem. 101-102 (Advanced Inorganic) Chem. 121-122 (Physical Chemistry) Chem. 163-164 (Quantitative Analysis)
171—Organic and Sanitary Analysis	Chem. 41-42 (Organic) Chem. 161-162 (Quantitative Analysis, Inorganic)
173-174—Advanced Organic Analysis	Chem. 171 (Organic and Sanitary Analysis) or equivalent work in Chem. 271-272 (Special methods of Organic Analysis)
176—Chemistry of Food and Nutrition	Chem. 41 (Elementary Organic)
69 or 170—Assaying	Chem. 3-4 (General Inorganic) Chem. 61-62 (Qualitative Analysis) Min. 1 (Descriptive and Determinative Mineralogy) or Min. 7 (Descriptive and Determinative Mineralogy)
160—Special Methods of Assaying Ores, Alloys and Furnace Products	Chem. 69 or 170 (Assaying)
81-82—Industrial Chemistry, general course	Chem. 3-4 (General Inorganic)
83-84—Industrial Chemistry, special course	Chem. 81-82 (Industrial Chemistry)
85-86—Industrial Chemistry, special course continued	Chem. 81-82 (Industrial Chemistry)
88—Industrial Chemistry, laboratory practice	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
89—Industrial Chemistry, laboratory practice	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
91-92—Chemical Microscopy	
92a—Microscopy	Chem. 65 (Quantitative Analysis, Inorganic)
95-96—Industrial Chemistry	
97—Chemical Factory Construction and Apparatus	
98—Chemical Factory Apparatus and Machines	
80a—Factory Inspection and Summer Memoir. (For Chem. and Chem. E.) (Second Year)	
80b—Factory Inspection and Summer Memoir. (For Chem. and without memoir for Chem. E.) (Third Year)	
93-94—Electro-Chemistry	
181 or 182—Practical Electro-Chemistry	Chem. 65 (Quantitative Analysis, Inorganic)
183-184—Industrial Electro-Chemistry	Chem. 65 (Quantitative Analysis, Inorganic)
Civil Engineering	
2—Theory of Surveying	
15—Surveying (between First and Second Years)	C.E. 2 (Theory of Surveying)
21—Highway Engineering	
23—Theory of Railroad Surveying	C.E. 15 (Surveying)
25—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
26—Surveying (between Third and Fourth Years)	C.E. 25 (Surveying)
27—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
28—Surveying (between Second and Third Years)	C.E. 23 (Theory of Railroad Surveying) C.E. 27 (Surveying)
51-52—Theory of Railroad Surveying	C.E. 15 (Surveying)
53-54—Elasticity and Resistance of the Materials of Engineering	Mech. 102 (Analytical Mechanics)
55—Standard Methods of Water Analysis	Zoology 7 (Sanitary Biology) C.E. 59 (Sanitary Engineering)

Subject	Prerequisite
Civil Engineering (*Continued*):	
57a—Statistics and Interpretation of Water Analysis	Zoology 7 (Sanitary Biology)
57b—Drainage of Marshes and Lowlands	C.E. 59 (Sanitary Engineering)
58—Masonry Structure	Zoology 7 (Sanitary Biology) C.E. 59 (Sanitary Engineering)
59—Sanitary Engineering	Mech. 102 (Analytical Mechanics)
61—Analytical Theory of Trusses	Min. 5 (Minerals of Building Stones) Chem. 81-82 (Industrial Chemistry)
62—Graphic Statics	Mech. 102 (Analytical Mechanics)
64—Graphic Statics (abridged course)	Mech. 102 (Analytical Mechanics)
71—Surveying (between Third and Fourth Years)	Mech. 102 (Analytical Mechanics)
75—Hydraulics	C.E. 51-52 (Theory of Railroad Surveying) C.E. 25 (Surveying)
76—Hydraulics. (For E.M.) (C.E. 75 abridged)	Mech. 102 (Analytical Mechanics) Mech. 102 (Analytical Mechanics)
77—Hydraulics. (For E.E.)	Mech. 102 (Analytical Mechanics)
78—Hydraulics. (For M.E.)	Mech. 102 (Analytical Mechanics)
85—Foundations	C.E. 58 (Masonry Structures) Geol. 18 (General Geology)
87-88—The Design and Construction of Bridges, Roofs and Buildings. (For Sanitary Engs.)	C.E. 53-54 (Elasticity and Resistance of the Materials of Engineering) C.E. 61 (Analytical Theory of Trusses) C.E. 62 (Graphic Statics)
89-90—Railroad Engineering	C.E. 71 (Surveying)
94—Design and Construction of Sewers, and River and Harbor Improvements	C.E. 26 (Surveying) C.E. 75 (Hydraulics)
95—Engineering Contracts and Specifications	
96—Principles of Hygiene, Sanitary Science and Public Health	57a (Statistics and Interpretation of Water Analysis) 57b (Drainage of Marshes and Lowlands)
98—Water-Supply and Irrigation Engineering	C.E. 26 (Surveying) C.E. 75 (Hydraulics)
99-100—Graduation Thesis	
Drafting	
1 or 2—Elements of Mechanical Drafting	
3 or 4—Descriptive Geometry	
5 or 6—Graphics	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
7 or 8—Structural Drafting	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
Economics	
2—Introduction to Economics	
Electrical Engineering	
1—Elements of Electrical Engineering	Phys. 4 (Sound, Light, Electricity and Magnetism)
2—Elements of the Dynamo	E.E. 1 (Elements of Electrical Engineering)
4—Electric Distribution (For E.M. Met.E. and C.E.) *Parallel* E.E. 72 (Direct Current Laboratory)	E.E. 2 (Elements of the Dynamo)
52—Design of Direct Current Machinery	E.E. 101 (Dynamo and Motor Practice)
54—Design of Alternating Current Machinery *Parallel* Mech. 110 Th. of Variable Currents)	E.E. 52 (Design of Direct Current Machinery) E.E. 104 (Electric Distribution)
72—Direct Current Laboratory *Parallel* E.E. 4 (Electric Distribution)	E.E. 2 (Elements of the Dynamo)

Subject	Prerequisite
Electrical Engineering (*Continued*):	
73—Direct Current Laboratory. (For M.E.) *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of the Dynamo)
75—Alternating Current Laboratory. (For E.M. and M.E.) (Short course)	E.E. 4 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
76—Alternating Current Laboratory. (For C.E.)	E.E. 4 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
98—Thesis *Parallel* Subjects of Fourth Year	All courses
101—Dynamo and Motor Practice *Parallel* E.E. 73 *or* 173-174 (Direct Current Laboratory)	E.E. 2 (Elements of the Dynamo)
103—Electric Power. (For E.E.) (For M.E.) E.E. 4 (Electric Distribution) E.E. 101 (Dynamo and Motor Practice)	E.E. 104 (Electric Distribution)
104—Electric Distribution	E.E. 101 (Dynamo and Motor Practice)
105—Electric Plants (For E.E.)	E.E. 104 (Electric Distribution)
105A—Electric Plants. (For M.E.)	E.E. 4 (Electric Distribution) E.E. 101 (Dynamo and Motor Practice)
106—Management of Electric Plants	E.E. 104 (Electric Distribution)
110—Telegraphy and Telephony	E.E. 2 (Elements of the Dynamo)
112—Electric Railway	E.E. 103 (Electric Power) E.E. 105 (Electric Plants)
173-174—Direct Current Laboratory *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of the Dynamo)
175-176—Alternating Current Laboratory *Parallel* Mech. 109 (Theory of Alternators and Transformers), Mech. 110 (Theory of Variable Currents), E.E. 105 (Electric Plants)	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
177—Instrument Laboratory	E.E. 173-174 (Direct Current Laboratory)
Geology	
4—Petrography	Min. 6 (Optical Mineralogy)
6—General Geology	Min. 1 (Descriptive and Determinative Mineralogy)
16—Index Fossils	Geol. 6 (General Geology)
18—General Geology	Min. 5 (Minerals of Building Stones)
19—Physiographic and Applied Geology	Geol. 18 (General Geology)
51—Principles of the Formation of Sedimentary Deposits	Geol. 6 (General Geology) *or* Geol. 18 (General Geology)
52—Discussion of Secondary Structural Features	Geol. 6 (General Geology) *or* Geol. 18 (General Geology)
105-106—Economic Geology	Geol. 6 (General Geology)
107-108—Invertebrate Palæontology	Antecedent work in Geology
110—Geological Examinations and Surveys	Geol. 105-106 (Economic Geology)
112—Field Geology	Geol. 6 (General Geology) Geol. 105-106 (Economic Geology) *desirable, not prerequisite*
201-202—Petrology	Geol. 4 (Petrography)
Law	
2—Business Law	
Mathematics	
1—Algebra	Entrance Mathematics
2—Differential Calculus	Math. 3 (Analytical Geometry)
3-4—Analytical Geometry	Entrance Mathematics
65—Differential and Integral Calculus	Math. 2 (Higher Trigonometry) Math. 3-4 (Analytical Geometry)

Subject	Prerequisite
Mechanical Engineering	
11-12—Steam Power Machinery. (For M.E.)	Phys. 3 (Elementary Mechanics and Heat)
13-14—Steam Power Machinery. (Short M.E. 11-12) (For other than M.E.)	Phys. 3 (Elementary Mechanics and Heat)
17-18—Technical Thermodynamics	M.E. 11-12 (Steam Power Machinery) *or* M.E. 13-14 (Steam Power Machinery) Mech. 102 (Analytical Mechanics)
19-20—Engine Design	M.E. 39-40 (Machine Design) M.E. 11-12 (Steam Power Machinery) M.E. 17-18 (Technical Thermodynamics)
22—Gas Power Machinery	M.E. 19 (Engine Design) M.E. 33 (Experimental Engineering)
25—Steam Power Plant Design	M.E. 96S (Power Plant Summer Work)
31-32—Experimental Engineering *Parallel* M.E. 17-18 (Technical Thermodynamics) Mech. 105 (Electric Plants)	M.E. 11-12 (Steam Power Machinery)
33—Experimental Engineering (Continuation of M.E. 31-32)	M.E. 96S (Power Plant Summer Work)
36—Kinematics of Machinery	Math. 3-4 (Analytical Geometry) M.E. 59 (Empiric Design)
39-40—Machine Design *Parallel* C.E. 53	M.E. 36 (Kinematics of Machinery)
41—Machine Design (Short course of M.E. 39-40) *Parallel* C.E. 53	
46—Water Power Machinery (For M.E.)	M.E. 36 (Kinematics of Machinery) M.E. 33 (Experimental Engineering) C.E. 78 (Hydraulics)
(For C.E.)	M.E. 76 (Experimental Engineering) C.E. 75 (Hydraulics) M.E. 78 (Kinematics of Machinery)
52—Works Management *Parallel* M.E. 68	
53—Steam Turbines. (For M.E.)	M.E. 17-18 (Technical Thermodynamics) M.E. 31-32 (Experimental Engineering)
(For E.E.)	M.E. 17-18 (Technical Thermodynamics) M.E. 76 (Experimental Engineering)
54—Principles of Machine Manufacture	M.E. 94S (Manufacturing Plant: Summer Work) M.E. 39 (Machine Design)
56—Water Power Installations *Parallel* M.E. 60 (Hydraulic Laboratory)	C.E. 77 (Hydraulics)
59—Empiric Design	Draft. 1 or 2 (Elements of Mechanical Drafting)
60—Hydraulic Laboratory. (For E.E.) *Parallel* (For M.E.) C.E. 78. (Hydraulics)	C.E. 77 (Hydraulics)
61—Seminar	
62—Refrigerating Machinery *Parallel* M.E. 18 (Tech. Thermodynamics)	M.E. 17 (Technical Thermodynamics)
63—Hydraulic Laboratory *Parallel* C.E. 75 (Hydraulics)	
64—Air Machinery	M.E. 17 (Technical Thermodynamics)
66—Elevators and Conveyors	M.E. 39 (Machine Design)
68—Manufacturing Plant Design *Parallel* M.E. 52 (Works Management)	E.E. 103 (Electric Power)
70—Pumping Machinery *Parallel* C.E. 78 (Hydraulics)	M.E. 17 (Technical Thermodynamics)
72—Gas Power Machinery	M.E. 17-18 (Technical Thermodynamics)
74—Gas Power Machinery	M.E. 17-18 (Technical Thermodynamics)
76—Experimental Engineering. (For E.M., Chem.E. and Met.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Technical Thermodynamics)
(For E.E.)	M.E. 17-18 (Technical Thermodynamics)
77—Experimental Engineering. (For C.E., Chem.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Technical Thermodynamics)

Subject	Prerequisite
Mechanical Engineering (*Continued*):	
78—Kinematics	M.E. 17-18 (Technical Thermodynamics) M.E. 76 (Experimental Engineering) Math. 3-4 (Analytical Geometry)
94S—Manufacturing Plant Summer Work	Sh.Wk. 1 (Wood Turning and Pattern Making) Sh.Wk. 2 (Molding and Foundry Practice) Sh.Wk. 12 (Forging)
82—Heating and Ventilation	M.E. 31-32 (Experimental Engineering)
96S—Power Plant Summer Work	M.E. 17-18 (Technical Thermodynamics)
Metallurgy	
101—General Metallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
111—Metallurgy of Copper	Met. 101 (General Metallurgy)
118—Metallurgy of Copper. (Advanced Course)	Met. 111 (Metallurgy of Copper)
122—Metallurgy of Lead, Silver, Gold and Zinc	Met. 111 (Metallurgy of Copper)
128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. (Advanced Course)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
131—Metallurgy of Iron and Steel Prerequisite or *Parallel* Met. 101 (General Metallurgy)	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
134—Metallurgy of Iron and Steel	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
138—Metallurgy of Iron and Steel. (Advanced Course)	Met. 131 (Metallurgy of Iron and Steel)
141—Electrometallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
148—Electrometallurgy. (Advanced Course)	Met. 141 (Electrometallurgy)
151—Constitution and Properties of Alloys	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
155-6—Metallography of Iron, Steel and Industrial Alloys	Met. 131 (Met. of Iron and Steel) *or* Met. 134 (Metallurgy of Iron and Steel)
158—Constitution and Properties of Alloys. (Advanced Course)	Met. 151 (Constitution and Properties of Alloys)
72—Metallurgical Laboratory *Parallel* Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)	Met. 111 (Metallurgy of Copper)
78—Thesis *Parallel* Met. 131 (Metallurgy of Iron and Steel), Met. 141 (Electrometallurgy)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc) Met. 171 (Metallurgical Laboratory)
171—Metallurgical Laboratory *Parallel* Met. 101 (General Metallurgy), Met. 111 (Metallurgy of Copper)	
175—Metallurgical Investigation *Parallel* Met. 131 (Metallurgy of Iron and Steel, and Met. 141 (Electrometallurgy)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc) Met. 171 (Metallurgical Laboratory)
64S—Summer Course in Ferrous Metallurgy	Met. 101 (General Metallurgy)
66S—Summer Course in Non-ferrous Metallurgy	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
177—Metallurgical Plant Construction	Draft. 7 or 8 (Structural Drafting) C.E. 53 (Elasticity and Resistance of Materials) Met. 64S (Summer Course in Ferrous Metallurgy) Met. 66S (Summer Course in Non-ferrous Metallurgy)

Subject	Prerequisite
Mineralogy	
1—Descriptive and Determinative Mineralogy	Entrance Chemistry Entrance Physics
5—The Minerals of Building Stones	Entrance Chemistry Entrance Physics
6—Optical Mineralogy	Min. 5 (Minerals of Building Stones) *or part of* Min. 1 (Descriptive and Determinative Mineralogy) *or equivalent*
7—Descriptive and Determinative Mineralogy. (Modification of Min. 1)	Entrance Chemistry Entrance Physics
15-16—Mineralogy	Entrance Chemistry Entrance Physics
Mining	
51—Excavation and Tunneling. (For E.M.)	Entrance Mathematics Entrance Chemistry Entrance Physics
52—Boring and Shaft Sinking. (For E.M. and C.E.)	E.M. 51 (Excavation and Tunneling)
53—Excavation, Tunneling, Boring and Shaft Sinking.) (For C.E.) (Condensation of E.M. 51 and 52)	Entrance Mathematics Entrance Chemistry Entrance Physics
54—Exploration, Development, and Methods of Working. (For E.M. and Met.E.) Prerequisite or *Parallel*	Geol. 105-106 (Economic Geology) E.M. 52 (Excavation and Tunneling)
56—Mine Engineering. (For E.M.) Prerequisite or *Parallel*	E.M. 71-72 (Mine Plant) C.E. 76 (Hydraulics) C.E. 28 (Surveying)
71-72—Mine Plant. (For E.M.)	E.M. 54 (Exploration, Development and Methods of Working) M.E. 13-14 (Steam Power Machinery)
73—Mine Constructions. (For E.M. and Met.E.)	
75—Design of Mine Plant. (For E.M.) *Parallel* E.M. 71-72 (Mine Plant)	Draft. 7 or 8 (Structural Drafting) C.E. 53 (Elasticity and Resistance of Materials)
77-78—Graduating Thesis or Project	All required subjects in Mining
80—Mill Construction	M.E. 13-14 (Steam Power Machinery)
81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. (For E.M. and Met.E.) *Parallel* or Prerequisite: Mech. 102 (Analytical Mechanics)	Min. 1 (Descriptive and Determinative Mineralogy) Phys. 3-4 (Elementary Mechanics and General Physics)
82—Ore-Dressing Laboratory. (For E.M. and Met.E.) *Parallel* or Prerequisite: E.M. 81 (Ore Dressing, Milling, and the Mechanical Preparation of Coal)	
91—Mine Administration. (For E.M. and Met.E.) *Parallel* E.M. 56 (Mine Engineering)	E.M. 54 (Exploration, Development and Methods of Working)
94—Mining Law	C.E. 27 (Surveying) E.M. 54 (Exploration, Development and Methods of Working)
95—Mining Conference. (Optional)	
58—Summer Class in Mine Surveying	C.E. 28 (Surveying)
59—Summer Course in Practical Mining *Parallels* or Prerequisites: E.M. 54 (Exploration, Development and Methods of Working)	M.E. 13 (Steam Power Machinery)

Subject	Prerequisite
Physical Education	
A1-A2	
B1-B2	Phys. Ed. A1-A2
Physics and Mechanics	
Phys. 3-4—Elementary Mechanics and General Physics	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 43-44—Intermediate Laboratory Course	Phys. 3-4 (Elementary Mechanics and General Physics)
Phys. 105—Electrical Measurements	Phys. 3-4 (Elementary Mechanics and General Physics)
Mech. 6—Analytical Mechanics	Phys. 3-4 (Elementary Mechanics and General Physics) Math. 65 (Differential and Integral Calculus)
Mech. 102—Analytical Mechanics	Phys. 3-4 (Elementary Mechanics and General Physics) Math. 65 (Differential and Integral Calculus)
Mech. 105—Thermodynamics	Mech. 102 (Analytical Mechanics)
Mech. 107-108—Theory of Electricity and Magnetism	Mech. 102 (Analytical Mechanics)
Mech. 109—Theory of Alternators and Transformers	Mech. 107-108 (Theory of Electricity and Magnetism)
Mech. 110—Theory of Variable Currents	Mech. 109 (Theory of Alternators and Transformers)
Shop Work	
1—Wood-turning and Pattern Making. (For M.E.)	
2—Molding and Foundry Practice. (For M.E.)	
10S—Machine Work. (For M.E.)	
11—Machine Work. (For M.E.)	
12—Forging. (For M.E.)	
13-14—Machine Work. (For E.E.)	
15—Forging and Foundry Practice. (For C.E.)	
16—Machine Work. (For C.E.)	
18S—Pattern-making. (For Chem.E.)	
Zoology	
7—Sanitary Biology	Bacteriology 101 (Sanitary Bacteriology)

SCHOOLS OF MINES, ENGINEERING AND CHEMISTRY

UNIFORM CURRICULUM FOR FIRST CLASS, 1910-1911

NOTE: Class to be divided alphabetically.

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Division A	9—10	Phys. 3. 301 F Phys. 4. 301 F	Mech. 1. Sec. II. 304, 506, 609 F Phys. 3. Sec. I. 615 F, 517, 609 Hm Phys. 4. 304, 506, 604, 609, 613, 615 F	Phys. 3. 301 F Phys. 4. 301 F	Mech. 1. Sec. II. 304, 506, 609 F Phys. 3. Sec. I. 615 F, 517, 609 Hm Phys. 4. 304, 506, 604, 609, 613, 615 F	Phys. 3. 301 F Phys. 4. 301 F	Chem. 61. Sec. I. 511 H. Sec. II. 306 E. Secs. III, IV. 301 H C. E. 2. 309 H, 305 S
	10—11	Math. 3. 307, 402, 406, 408, 507, 602 Hm Math. 4. 202, 203, 213, 307, 408, 507, 602 Hm	Math. 1. 303, 307, 309, 408, 501, 502 Hm Math. 2. 202, 203, 213, 214, 303, 307, 501 Hm	Math. 3. 307, 402, 406, 408, 507, 602 Hm Math. 4. 202, 203, 213, 307, 408, 507, 602 Hm	Math. 1. 303, 307, 309, 408, 501, 502 Hm Math. 2. 202, 203, 213, 214, 303, 307, 501 Hm	Math. 3. 307, 402, 406, 408, 507, 602 Hm Math. 4. 202, 203, 213, 307, 408, 507, 602 Hm	Chem. 61. Secs. I, II. 301 H. Sec. III. 309 H. Sec. IV. 311 H Chem. 4. 306 E
	11—12	Chem. 3-4. 309 H	Mech. 1. Sec. I. 304, 506, 609 F Phys. 3. Sec. II. 303, 517, 609 Hm Dft. 4. 306 E, 604 F, 306 M.	Chem. 3. 506, 410 E. 301, 302 M C. E. 2. 402 E, 301 M, 301 U	Mech. 1. Sec. I. 304, 506, 609 F Phys. 3. Sec. II. 303, 517, 609 Hm Dft. 4. 306 E, 604 F, 306 M	Chem. 3-4. 309 H	Dft. 4. 306 E, 604, 609 F
	1—2	Dft. 2. Sec. I. 306 E	Chem. 61. Secs. I, II. 309 H. Sec. III. 301 M. Sec. IV. 413 H	Dft. 2. Sec. II. 306 E	Chem. 61. Sec. I. 311 H. Sec. II. 413 H. Secs. III, IV. 309 H		
	1—4	Chem. 61, Lab. 515 H Dft. 2. 601 E	Chem. 61, Lab. 515 H Dft. 2. 601 E	Chem. 61, Lab. 515 H Dft. 2. 601 E	Chem. 61, Lab. 515 H Dft. 2. 601 E	Chem. 61, Lab. 515 H Dft. 2. 601 E	
	4—5		Phys. Ed. A1-A2 (Gym.)			Phys. Ed. A1-A2 (Gym.)	
Division B	9—10	Math. 3-4. 202, 203, 213, 214, 307, 501 Hm	Math. 1-2. 202, 203, 213, 214, 303 Hm	Math. 3-4. 202, 203, 213, 214, 307, 501 Hm	Math. 1-2. 202, 203, 213, 214, 303 Hm	Math. 3-4. 202, 203, 213, 214, 307, 501 Hm	Chem. 3. 311, 611 H, 301 M C. E. 2. 309 H, 305 S
	10—11	Phys. 3. 301 F Phys. 4. 301, 615 F, 607, 609, 613 Hm, 301 U	Mech. 1. Sec. III. 506, 609 F, 214 Hm Phys. 3. Sec. IV. 615 F, 517, 609 Hm Phys. 4. 304, 604, 615 F, 309, 408, 502 Hm	Phys. 3. 301 F Phys. 4. 301, 615 F, 607, 609, 613 Hm, 301 U	Mech. 1. Sec. III. 506, 609 F, 214 Hm Phys. 3. Sec. IV. 615 F, 517, 609 Hm Phys. 4. 304, 604, 615 F, 309, 408, 502 Hm	Phys. 3. 301 F Phys. 4. 301, 615 F, 607, 609, 613 Hm, 301 U	Mech. 1. Sec. IV. 304, 609 F, 502 Hm Phys. 3. Sec. III. 517, 609, 613 Hm Chem. 62. Sec. I, II. 309 H. Sec. III. 301 H. Sec. IV. 611 H
	11—12	Chem. 3-4. 309 H	Dft. 3. 410 E, 604 F, 306 M C. E. 2. 302 E, 301 M, 301 U	Mech. 1. Sec. IV. 304, 609 F, 502 Hm Phys. 3. Sec. III. 517, 609, 613 Hm	Dft. 3. 410 E, 604 F, 306 M Chem. 4. 304, 615 F, 301, 309 H	Chem. 3-4. 309 H	Dft. 3. 410 E, 604 F, 306 M Chem. 62. Sec. I. 301 H. Sec. II. 611 H. Sec. III, IV. 309 H
	1—2	Dft. 1. Sec. I. 306 E	Chem. 62. Secs. I, II. 309 H. Sec. III. 301 H. Sec. IV. 413 H	Dft. 1. Sec. II. 306 E	Chem. 62. Sec. I. 301 H. Sec. II. 413 H. Sec. III, IV. 309 H		
	1—4	Dft. 1. 601 E Chem. 62, Lab. 515 H	Dft. 1. 601 E Chem. 62, Lab. 515 H	Dft. 1. 601 E Chem. 62, Lab. 515 H	Dft. 1. 601 E Chem. 62, Lab. 515 H	Dft. 1. 601 E Chem. 62, Lab. 515 H	
	4—5	Phys. Ed. A1-A2 (Gym.)			Phys. Ed. A1-A2 (Gym.)		

E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. U=University. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF CHEMISTRY

COURSE IN CHEMICAL ENGINEERING, 1910-1911

NOTE: See Uniform Curriculum for First Class

	Hours	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10	Chem. 81-82. 309 H	Chem. 41-42. 413 H	Chem. 81-82. 309 H	Phys. 5. 301 E E. E. 2. 301 E	Chem. 81-82. 309 H	Chem. 41-42. 413 H
	10—11	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Phys. 5. 301 E E. E. 2. 301 E
	11—12		Chem. 163. 511 H Chem. 164. 511 H		Chem. 163. 511 H Chem. 164. 511 H	Chem. 163. 413 H Chem. 164. 413 H	Chem. 163. 511 H Chem. 164. 511 H
	1—2		Dft. 7. 302 E				
	1—4	Mineral. 15-16. 106 S	Dft. 7. 607 E Chem. 164, Lab. 504 H	Dft. 7. 607 E Chem. 164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Chem. 163-164, Lab. 504 H
	4—5	Phys. Ed. B, Gym.			Phys. Ed. B, Gym.		
		Shop-work 18s, 3 weeks in June.					
Third Class	9—10	E. E. 4. 301 E	Mech. E. 13-14. 309 H	E. E. 4. 301 E	Mech. E. 13-14. 309 H	Chem. 171. 511 H Mech. E. 14. 410 E	Met. 131, 141. 306 M
	10—11	Chem. 83-84. 309 H	Mech. E. 59. 510 E	Chem. 83-84. 309 H	Mech. E. 59. 510 E	Chem. 83-84. 309 H	Chem. 171. 609 H
	11—12	C. E. 53. 301 E Chem. 150. 311 H	C. E. 53. 301 E	C. E. 53. 301 E Chem. 150. 311 H	C. E. 53. 301 E Mech. E. 70. 311 H	C. E. 53. 301 E	Mech. E. 13. 301 E Mech. E. 70. 311 H
	1—2		Chem. 171. 311 H	Chem. 171. 511 H	Met. 131, 141. 306 M		
	1—4	C. E. 53. 402 E Chem. 150, Lab. 405 H	Chem. 171, Lab. 504 H C. E. 54, Lab. 308 E	Chem. 171, Lab. 504 H E. E. 72, Lab. 201 E	Chem. 171, Lab. 504 H Chem. 150, Lab. 405 H	Mech. E. 59. 510 E Chem. 150, Lab. 405 H	
Fourth Class	9—10	Met. 101, 111. 306 M Chem. 122. 511 H	C. E. 77. 302 E Mech. E. 76. 402 E	Met. 101, 111 (2). 306 M Chem. 122. 511 H	C. E. 77. 302 E Chem. 98. 311 H	Met. 101, 111. 306 M Chem. 122. 511 H	Mech. E. 17. 309 H
	10—11	Chem. 85-86. 309 H	Chem. 97. 301 H Chem. 184. 311 H	Chem. 85-86. 309 H	Chem. 97. 301 H Chem. 184. 311 H	Chem. 85-86. 309 H	Chem. 97. 611 H Mech. E. 18. 302 E
	11—12	Chem. 121. 511 H Met. 122. 306 M	Mech. E. 39. 302 E Mech. E. 18. 309 H	Chem. 121. 511 H Met. 122. 306 M	Mech. E. 17. 302 E Mech. E. 52. 511 H	Chem. 121. 511 H Met. 122. 306 M	Mech. E. 77. 302 E Mech. E. 52. 511 H
	1—4	Mech. E. 39. 510 E	Chem. 89 & 121 (see below) Mech. E. 76, Lab. WV	Chem. 89 & 121 (see below)	Mech. E. 77, Lab. WV	Mech. E. 39. 510 E	Chem. 89 & 121 (see below)
		Chem. 89, Lab. 414 H, September to December, 1910 Chem. 121, Lab. 410 H, December, 1910, to January, 1911 Chem. 184, Lab. 102 H. Total of 14 afternoons as assigned Met. 72, Lab. 401 M. Total of 10 afternoons as assigned Thesis. Afternoons not taken in Chem. 184, Met. 72 or Mech. E. 76					

*During December and January. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF CHEMISTRY

COURSE IN CHEMISTRY, 1910-1911

NOTE: See Uniform Curriculum for First Class.

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Chem. 81-82. 309 H	Chem. 41. 413 H Chem. 42. 413 H	Chem. 81-82. 309 H	Phys. 5. 301 E E. E. 2. 301 E	Chem. 81-82. 309 H	Chem. 41. 413 H Chem. 42. 413 H
	10—11	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Phys. 5. 301 E E. E. 2. 301 E
	11—12	Chem. 22. 511 H	Chem. 163-164. 511 H	Chem. 22. 511 H	Chem. 163-164. 511 H	Chem. 163-164. 413 H	Chem. 163-164. 511 H
	1—2		Chem. 21-22. 511 H	Chem. 21. 413 H			
	1—4	Mineral. 15-16. 106 S	Chem. 163, Lab. 504 H Chem. 164, Lab. 504 H. During Feb., March and April, 1911. Chem. 22, Lab. 410 H. During May, 1911				
	4—5	Phys. Ed. B, Gym.			Phys. Ed. B, Gym.		
Third Class	9—10	Chem. 102. 413 H	Mech. E. 13-14. 309 H	Chem. 102. 413 H	Mech. E. 13-14. 309 H	Chem. 171. 511 H Mech. E. 14. 410 E	Met. 131, 141. 306 M
	10—11	Chem. 83-84. 309 H	Mech. E. 13. 410 E Chem. 92. 414 H	Chem. 83-84. 309 H	Chem. 183. 311 H Chem. 92. 414 H	Chem. 83-84. 309 H	Chem. 171. 511 H
	11—12	Chem. 170. 301 H	Chem. 91. 414 H Chem. 92. 414 H	Chem. 101. 301 H Chem. 170. 301 H	Chem. 91. 414 H Chem. 92. 414 H	Chem. 184. 311 H	Chem. 101. 311 H
	1—2		Chem. 171. 511 H	Chem. 171. 511 H	Met. 131, 141. 306 M		
	1—4	Chem. 91. 414 H Chem. 88, Lab. 414 H	Chem. 171, Lab. 504 H Chem. 184, Lab. 102 H	Chem. 171, Lab. 504 H Chem. 170, Lab. 107 H	Chem. 171, Lab. 504 H Chem. 170, Lab. 107 H	Chem. 171, Lab. 504 H Chem. 170, Lab. 107 H	Chem. 171, Lab. 504 H Chem. 88, Lab. 414 H
Fourth Class	9—10	Met. 101, 111. 306 M Chem. 122. 511 H		Met. 101, 111. 306 M Chem. 122. 511 H		Met. 101, 111. 306 M Chem. 122. 511 H	*†Met. 131. 306 M
	10—11	Chem. 85-86. 309 H	Chem. 141-142. 413 H	Chem. 85-86. 309 H	Chem. 141-142. 413 H	Chem. 85-86. 309 H	Chem. 141-142. 413 H
	11—12	Chem. 121. 511 H Metal. 122 (2). 306 M	Chem. 141-142. 413 H	Chem. 121. 511 H Met. 122 (2). 306 M	Chem. 141-142. 413 H	Chem. 121. 511 H Met. 122 (2). 306 M	
	1—2				*†Met. 131. 306 M		
	1—4		Chem. 89, Lab. 414 H. Sept. 22 to Oct., 1910 Chem. 141, Lab. 405 H. Oct., 1910, to Jan., 1911 Chem. 121, Lab. 410 H. Jan. 6th to Jan., 1911 *b* Thesis				

b Second term only. *First half of term. †For students not having credit in this subject. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. U=University. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF ENGINEERING

COURSE IN CIVIL ENGINEERING, 1910-1911

NOTE: See Uniform Curriculum for First Class.

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Mineral. 5. 516 S Chem. 82. 309 H	Mech. E. 13-14. 309 H	C. E. 21. 402 E Chem. 82. 309 H	Mech. E. 13-14. 309 H	C. E. 21. 402 E Chem. 82. 309 H	Bot. 7. 505 S Mech. E. 14. 410 E
	10—11	Phys. 5. 301 E E. E. 2. 301 E	Min'g 53. 301 M Geol. 18. 305 S	Phys. 5. 301 E E. E. 2. 301 E	Min'g 53. 301 M Met. 134. 306 M	Mineral. 5. 516 S Geol. 18. 401 S	Min'g 53. 301 M Geol. 18. 305 S
	11—12	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Mech. E. 13. 301 E Met. 134. 306 M
	1—2	Dft. 8. Div. B. 410 E	Dft. 5. Div. B. 306 E		Dft. 5. Div. A. 306 E	Dft. 8. Div. A. 306 E	
	1—4 Div. A	Mineral. 5, Lab. 106 S Phys. 44, Lab. 408 F	Sh. Wk. 15-16. Lab. Secs. I, II. 31 T Dft. 8. Sec. III. 601 E	Bot. 7 502 S Sh. Wk. 16. Sec. III. 31 T Dft. 8. Secs. I, II. 601 E	Dft. 5. 601 E Phys. 44, Lab. 408 F	Dft. 5. 601 E Dft. 8. 601 E	Sh. Wk. 15, Lab. Sec. III. 31 T Geol. 18, Lab. and fieldwork
	1—4 Div. B	Mineral 5. Lab. 106 S Dft. 8. 601 E	Dft. 5. 601 E Phys. 44, Lab. 408 F	Dft. 5. 601 E Sh. Wk. 16, Lab. Sec. IV. 125 T Dft. 8. Secs. V, VI	Sh. Wk. 15, Lab. Sec. V, VI. 31 T Dft. 8. Sec. IV. 601 E Sh. Wk. 16. Secs. V, VI. 125 T	Bot. 7. 502 S Phys. 44, Lab. 408 F	Sh. Wk. 15. Sec. IV Geol. 18, Lab. and fieldwork
	4—5	Phys. Ed. B, Gym. Sec. I	Phys. Ed. B, Gym. Sec. II	Phys. Ed. B, Gym. Sec. I	Phys. Ed. B, Gym. Sec. II		
Third Class	9—10	Mech. E. 17. 410 E E. E. 4. 301 E	Mech. E. 78. 510 E	C. E. 59. 306 E E. E. 4. 301 E	C. E. 61. 306 E Mech. E. 78. 510 E	C. E. 59. 306 E	Mech. E. 17. 309 H
	10—11	C. E. 53. 306, 402 E C. E. 58. 402 E	C. E. 53. 306, 402 E C. E. 52. 402 E	C. E. 53. 306, 402 E C. E. 58. 402 E	C. E. 53. 306, 402 E C. E. 52. 402 E	C. E. 53. 306, 402 E C. E. 58. 402 E	Mech. E. 77. 402 E C. E. 52. 402 E
	11—12	Ast. 105. 604 F Mech. E. 18. 302 E	C. E. 51. 402 E Mech. E. 18. 309 H	Ast. 105-106. 604 F	C. E. 51. 402 E C. E. 62. 301 M	Ast. 105. 604 F Mech. E. 78. 510 E	C. E. 61. 402 E C. E. 62. 301 E
	1—4 Sec. I	C. E. 53. 308 E C. E. 54. 402 E	Mech. E. 77, Lab. WV C. E. 58. 406 E	*C. E. 61. 406 E **C. E. 59, Lab. Ast. 106. 609 F	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53. 402 E E. E. 72, Lab. 201 E	C. E. 52. 402 E
	1—4 Sec. II	C. E. 53. 301 E E. E. 72 Lab. 201 E	C. E. 58. 406 E	*C. E. 61. 406 E **C. E. 59, Lab. Ast. 106. 609 F	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53, Lab. 308 E C. E. 54. 402 E	Mech. E. 77, Lab. WV C. E. 52. 402 E
Fourth Class	9—10	C. E. 94. 410 E	C. E. 87-88. 402 E	C. E. 94. 410 E	C. E. 87-88. 402 E	C. E. 100	E. E. 76. 301 H
	10—11	C. E. 75. 302 E C. E. 98. 302 E	C. E. 89. 301 E Mech. E. 46. 301 H	C. E. 75. 302 E C. E. 98. 302 E	C. E. 89. 301 E Mech. E. 46. 301 H	Mech. E. 41. 301 E C. E. 100	C. E. 89. 306 E Mech. E. 46. 301 H
	11—12	C. E. 85. 402 E E. E. 112. 502 E	C. E. 75. 302 E C. E. 90. 402 E	C. E. 85. 402 E E. E. 112. 502 E	C. E. 95. 301 M C. E. 90. 402 E	C. E. 75. 302 E C. E. 100	C. E. 95. 301 M C. E. 90. 402 E
	1—4 Sec. I	Mech. E. 41. 510 E E. E. 76. 202 E	C. E. 89. 404 E C. E. 90. 404 E	C. E. 99 C. E. 88. 404 E	C. E. 87. 404 E C. E. 100	C. E. 85. 404 E C. E. 100	Mech. E. 63, Lab. WV
	1—4 Sec. II	Mech. E. 63, Lab. WV C. E. 100	C. E. 89. 404 E C. E. 90. 404 E	Mech. E. 41. 510 E C. E. 88. 404 E	C. E. 87. 404 E C. E. 100	C. E. 85. 404 E E. E. 76. 202 E	C. E. 99

*Except two afternoons in January. **Two afternoons in January. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF ENGINEERING

COURSE IN ELECTRICAL ENGINEERING, 1910-1911

NOTE: See Uniform Curriculum for First Class

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Chem. 81-82. 309 H	Mech. E. 13-14. 309 H	Chem. 81-82. 309 H	Mech. E. 13-14. 309 H	Chem. 81-82. 309 H	Dft. 6-8. 609 H
	10—11	Phys. 5. 301 E E. E. 2. 301 E	Mech. E. 13. 410 E Met. 134. 306 M	Phys. 5. 301 E E. E. 2. 301 E	Chem. 65. 511 H Met. 134. 306 M	Phys. 105. 304 F Chem. 38. 511 H	Chem. 65. 511 H Chem. 38. 511 H
	11—12	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Phys. 105. 304 F Mech. E. 14. 410 E
	1—4	Dft. 6-8. 601 E	Phys. 43, Lab. 408 F Dft. 6-8. 601 E	Sh. Wk. 13, Lab. 125 T Dft. 6-8. 601 E	Phys. 43, Lab. 408 F Dft. 6-8. 601 E	Chem. 65, Lab. 504 H Sh. Wk. 14, Lab. 125 T	Chem. 65, Lab. 504 H
	4—5	Phys. Ed. B, Gym.			Phys. Ed. B, Gym.		
Third Class	9—10	E. E. 101. 301 E E. E. 104. 302 E	C. E. 77. 302 E Econ. 2. 401 S	E. E. 101. 301 E E. E. 104. 302 E	C. E. 77. 302 E Econ. 2. 401 S	Mech. E. 17. 302 E E. E. 104. 502 E	Mech. E. 17. 309 H Mech. E. 76, Lab. Sec. I. WV Mech. E. 36. Sec. II. 510 E
	10—11	C. E. 53. 306, 402 E Mech. 108. 311 H	C. E. 53. 306, 402 E E. E. 52. 302 E	C. E. 53. 306, 402 E Mech. 108. 311 H	C. E. 53. 306, 402 E E. E. 52. 302 E	C. E. 53. 306, 402 E Mech. 108. 311 H	Mech. E. 76, Lab. Sec. I. WV Mech. E. 36. Sec. II. 510 E
	11—12	Mech. 105. 311 H	Mech. 107. 615 F Mech. E. 18. 309 H	Mech. 105. 311 H Mech. E. 76. 302 E	Mech. 107. 615 F Mech. E. 18. 410 E	Mech. E. 41. 410 E	Mech. E. 76, Lab. Sec. I. WV Mech. E. 36. Sec. II. 510 E
	1—2					Econ. 2. 301 E	
	1—4 Sec. I	Mech. E. 41. 510 E Mech. E. 36. 510 E	Mech. E. 36. 510 E	E. E. 173, Lab. 201 E E. E. 52. 502 E	E. E. 173, Lab. 201 E	C. E. 53. 301 E	C. E. 53, Lab. 308 E E. E. 174, Lab. 201 E
	1—4 Sec. II	C. E. 53. 301 E	C. E. 53, Lab. 308 E Mech. E. 76, Lab. WV	Mech. E. 41. 510 E E. E. 52. 502 E		E. E. 173, Lab. 201 E Mech. E. 36. 510 E	E. E. 173, Lab. 201 E E. E. 174, Lab. 201 E
Fourth Class	9—10	E. E. 175. Sec. II. 202 E Mech. 110. 301 H	Mech. E. 53. 306 M §E. E. 176. 202 E	Mech. 109. 301 H Mech. 110. 301 H	Mech. E. 53. 306 M E. E. 110. 302 E	E. E. 175. Sec. I. 202 E	E. E. 105. 302 E E. E. 110. 302 E
	10—11	E. E. 177. Sec. I. 502 E E. E. 175. Sec. II. 202 E E. E. 54. 502 E	E. E. 105. 302 E §E. E. 176. 202 E	Chem. 183. 301 H E. E. 54. 502 E	E. E. 105. 302 E Mech. E. 72. 410 E	E. E. 175. Sec. I. 202 E E. E. 177. Sec. II. 502 E Mech. E. 56. 301 E	Mech. 109. 502 E Mech. E. 72. 410 E
	11—12	E. E. 103. Sec. I. 502 E E. E. 175. Sec. II. 202 E E. E. 112. 502 E	E. E. 103. 306 E §E. E. 176. 202 E	Mech. E. 77. 302 E E. E. 112. 502 E	E. E. 103. 306 E E. E. 106. 302 E	E. E. 175. Sec. I. 202 E E. E. 103. Sec. II. 502 E E. E. 176. 202 E	Chem. 183. 301 H E. E. 106. 302 E
	1—2		Mech. 109. 301 H	Mech. 109. 301 H			
	1—4 Sec. I	E. E. 175, Lab. 202 E	E. E. 177, Lab. 501 E E. E. 176, Lab. 202 E	E. E. 177, Lab. 501 E E. E. 176, Lab. 202 E	Chem. 183, Lab. 102 H	Mech. E. 77, Lab. WV Mech. E. 72, Lab. WV	Chem. 183, Lab. 102 H *Mech. E. 60, Lab. WV
	1—4 Sec. II	Mech. E. 77, Lab. WV *Mech. E. 60, Lab. WV	Chem. 183, Lab. 102 H	Chem. 183, Lab. 102 H Mech. E. 72, Lab. WV	E. E. 177, Lab. 501 E E. E. 176, Lab. 202 E	E. E. 175, Lab. 202 E	E. E. 177, Lab. 501 E E. E. 176, Lab. 202 E

*Last half of term only. §As assigned. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF ENGINEERING

COURSE IN MECHANICAL ENGINEERING, 1910-1911

NOTE: See Uniform Curriculum for First Class.

	Hours		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10		Chem. 81-82. 309 H	Mech. E. 11-12. 309 H	Chem. 81-82. 309 H	Mech. E. 11-12. 309 H	Chem. 81-82. 309 H	
	10—11		Phys. 5. 301 E E. E. 2. 301 E	Mech. E. 59. 510 E Met. 134 (2). 306 M	Phys. 5. 301 E E. E. 2. 301 E	Mech. E. 59. 510 E Met. 134 (2). 306 M	Mech. E. 11. 410 E Mech. E. 12. 410 E	Phys. 43, Lab. Sec. I. 408 F Sh.Wk. 1, Lab. Sec. II. 119 T.
	11—12		Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Mech. E. 36. Sec. I. 510 E Sh.Wk. 12, Lab. Sec. II. 29 T
	1—2					Dft. 7. 302 E		
	1—4	Sec. I	Sh. Wk. 1, Lab. 119 T †Sh. Wk. 12, Lab. 29 T	Mech. E. 59. 510 E Sh. Wk. 12, Lab. 29 T	Phys. 43, Lab. 408 F †Sh. Wk. 2, Lab. 31 T	Dft. 7. 601 E Mech. E. 12. Lab. WV	Sh. Wk. 1, Lab. 119 T Mech. E. 36. 510 E	
		Sec. II	Phys. 43, Lab. 408 F Mech. E. 36. 510 E	Mech. E. 59. 510 E Mech. E. 36. 510 E	Sh. Wk. 1, Lab. 119 T Mech. E. 12, Lab. WV	Dft. 7. 601 E Sh. Wk. 2, Lab. 31 T	Phys. 43, Lab. 408 F †Sh. Wk. 12, Lab. 29 T	
	4—5		Phys. Ed. B, Gym. Sec. II	Phys. Ed. B, Gym. Sec. I		Phys. Ed. B, Gym. Sec. II	Phys. Ed. B, Gym. Sec. I	
Third Class	9—10		E. E. 101. 301 E E. E. 4. 301 E	Mech. E. 31. 410 E Mech. E. 32. 410 E	E. E. 101. 301 E E. E. 4. 301 E	*Mech. E. 60. 306 M §Met. 156. 306 M	Mech. E. 64. 302 E	Sh.Wk. 11, Lab. Sec. I. 125 T Mech.E.31, Lab. Sec. II. WV Mech. E. 66. 301 M
	10—11		C. E. 53. 306, 402 E Mech. E. 40. 301 M	C. E. 53. 306, 402 E C. E. 78. 301 E	C. E. 53. 306, 402 E Mech. E. 62. 301M	C. E. 53. 306, 402 E C. E. 78. 301 E	C. E. 53. 306, 402 E Mech. E. 64. 302 E	Sh.Wk. 11, Lab. Sec. I. 125 T Mech.E. 31, Lab. Sec.II. WV Mech. E. 40. 301 M
	11—12		Mech. 105. 311 H Mech. E. 54. 301 E	Mech. E. 39. 301 M Mech. E. 18. 309 H	Mech. 105. 311 H Mech. E. 54. 301 E	Mech. E. 17. 302 E Mech. E. 70. 311 H	Mech. E. 17. 301 M Mech. E. 18. 302 E	Sh.Wk. 11, Lab. Sec. I. 125 T Mech.E.31, Lab. Sec. II. WV Mech. E. 70. 311 H
	1—4	Sec. I	†Sh. Wk. 11, Lab. 125 T *Mech. E. 60, Lab. WV **Met. 156. 508 M	E. E. 73, Lab. 201 E Mech. E. 40. 510 E	Mech. E. 31,Lab. WV Mech. E. 40. 510 E	Mech. E. 39. 510 E C. E. 54, Lab. 308 E	C. E. 53. 301 E Mech. E. 32, Lab. WV	Mech. E. 39. 510 E **Met. 156 (2), 508
		Sec. II	E. E. 73, Lab. 201 E **Met. 156. 508 M	Sh. Wk. 11, Lab. 125 T Mech. E. 40. 510 E	Mech. E. 39. 510 E Mech. E. 40. 510 E	Sh. Wk. 11, Lab. 125 T Mech. E. 32,Lab. WV	C. E. 53. 301 E C. E. 54, Lab. 308 E	Mech. E. 39. 510 E *Mech. E. 60, Lab. WV **Met. 156, 508
Fourth Class	9—10		Mech. E. 19. 506 E Mech. E. 22, Lab. Sec. I. WV Mech. E.20. Sec. II. 506 E	Mech. E. 53. 306 M Econ. 2. 401 S	Mech. E. 19. Sec. I. 506 E Mech. E. 33. Sec. II. WV Mech. E. 20. 506 E	Mech. E. 53. 306 M Econ. 2. 401 S	Mech. E. 33, Lab. Sec. I. WV Mech. E. 19. Sec. II. 506 E Mech. E. 20. Sec. I. 506 E Mech. E. 22. Sec. II. WV	Mech. E. 25. 506 E Mech. E. 22. 306 E
	10—11			E. E. 105. 302 E Mech. E. 68. 410 E		E. E. 105. 302 E Mech. E. 46. 301 H		Mech. E. 25. 506 E Mech. E. 46. 301 H
	11—12			E. E. 103. 306 E Mech. E. 68. 410 E		E. E. 103. 306 E Mech. E. 52. 301 U		Mech. E. 25. 506 E Mech. E. 52. 301 U
	1—2		Mech. E. 25. 302 E Mech. E. 22. 302 E	E. E. 75. Sec. I. 202 E Mech. E. 25. Sec. II. 506 E Mech. E. 22. 302 E	Mech. E. 25. 302 E Mech. E. 22. 302 E		Mech. E. 25. 302 E Econ. 2. 301 E	
	2—3		Mech. E. 33. 302 E Law 2. 302 E	E. E. 75, Lab. Sec. I. 202 E Mech. E. 25. Sec. II. 506 E	Mech. E. 33. 302 E Law 2. 302 E	Mech. E. 25. Sec. I. 506 E E. E. 75. Sec. II. 202 E Mech. E. 68. 510 E	Mech. E. 61. 506 E Law 2. 302 E	
	3—4		Mech. E. 19-20. 302 E	E. E. 75, Lab. Sec. I. 202 E Mech. E. 25. Sec. II. 506 E Mech. E. 46. 301 E	Mech. E. 19-20. 302 E		Mech. E. 19-20. 302 E	

*First half of term. §Second half of term. **Seven afternoons in second half of term. †2-5 P.M. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF MINES

NOTE: See Uniform Curriculum for First Class

COURSE IN METALLURGICAL ENGINEERING, 1910-1911

	Hours	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10	Chem. 81-82. 309 H	C. E. 23. 306 E Chem. 66. 301 E	Chem. 81-82. 309 H	Phys. 5. 301 E E. E. 2. 301 E	Chem. 81-82. 309 H	C. E. 23. 402 E Chem. 66. 301 E
	10—11	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Phys. 5. 301 E E. E. 2. 301 E
	11—12	Mineral. 7. 516 S Geol. 6. 401 S	Mineral. 7. 516 S Geol. 6. 401 S	Min. 7. 516 S Geol. 6. 401 S	Mineral. 7. 516 S Geol. 6. 401 S	Mineral. 7. 516 S Geol. 6. 401 S	Mineral. 7. 516 S Geol. 6. 401 S
	1—2				Chem. 66. 311, 511 H		
	1—4	Phys. 43, Lab. 408 F Dft. 8. 601 E	C. E. 23. 402 E Chem. 66, Lab. 504 H	Mineral. 7, Lab. 106 S Chem. 66, Lab. 504 H	Mineral. 7, Lab. 106 S Chem. 66, Lab. 504 H	Phys. 43, Lab. 408 F Chem. 66, Lab. 504 H	
	4—5	Phys. Ed. B, Gym.			Phys. Ed. B, Gym.		
Third Class	9—10	Met. 101, 111. 306 M E. E. 4. 301 E	Mech. E. 13-14. 309 H	Met. 101, 111. 306 M E. E. 4. 301 E	Mech. E. 13-14. 309 H	Met. 101, 111. 306 M	Mech. E. 17. 309 H C. E. 64. 402 E
	10—11	Mech. E. 13. 410 E Mech. E. 76. 410 E	Geol. 105-106. 401 S	Mech. E. 17. 410 E	Geol. 105-106. 401 S	Chem. 69. 301 H Mech. E. 14. 410 E	Geol. 105-106. 401 S
	11—12	C. E. 53. 301 E Met. 122. 306 M	C. E. 53. 301 E Min'g 54. 302 M	C. E. 53. 301 E Met. 122. 306 M	C. E. 53. 301 E Min'g 54. 302 M	C. E. 53. 301 E Met. 122. 306 M	Min'g 54. 302 M
	1—2				Chem. 69. 301 H		
	1—4	C. E. 53. 301 E Mech. E. 76, Lab. WV	Met. 171, Lab. 501 M C. E. 54, Lab. 308 E	Met. 171, Lab. 501 M E. E. 72, Lab. 201 E	Chem. 69, Lab. 107 H	Chem. 69, Lab. 107 H C. E. 54. 402 E	Chem. 69, Lab. 107 H C. E. 64. 510 E
Fourth Class	9—10	Chem. 122. 511 H	Min'g 91. 302 M Met. 148. 306 M	E. E. 75. 302 E Chem. 122. 511 H	Min'g 91. 302 M	Chem. 122. 511 H	Met. 131-141. 306 M Met. 138. 306 M
	10—11	Met. 151. 306 M Met. 118. 306 M	Met. 175. 306 M Min'g 80. 302 M	Met. 151. 306 M Met. 128. 306 M	Min'g 73. 302 M Mech. E. 72. 410 E	Met. 151. 306 M Min'g 94. 301 M	Min'g 81. 302 M Mech. E. 72. 410 E
	11—12	Chem. 121. 511 H	Min'g 81. 302 M C. E. 76. 301 E	Chem. 121. 511 H	Min'g 81. 302 M C. E. 76. 301 E	Chem. 121. 511 H	Min'g 81. 302 M Min'g 94. 301 M
	1—2				Met. 131, 141. 306 M		
	1—4	†Met. 177. §Chem. 121, Lab. 410 H **Min'g 82, Lab. 201 M †Met. 78. Thesis	†Met. 177, Lab. §Chem. 121, Lab. 410 H **Min'g 82, Lab. 201 M †Met. 78. Thesis	†Met. 177, Lab. §Chem. 121, Lab. 410 H **Min'g 82, Lab. 201 M †Met. 78. Thesis	†Met. 177, Lab. §Chem. 121, Lab. 410 H **Min'g 82, Lab. 201 M †Met. 78. Thesis	†Met. 177, Lab. §Chem. 121, Lab. 410 H **Min'g 82, Lab. 201 M †Met. 78. Thesis	E. E. 75, Lab. 202 E Mech. E. 72, Lab. WV

**Three weeks consecutive afternoons. †Afternoons not assigned to Chemistry 121 or Mining 82. §January 6 to 18, 1911. E=Engineering. F=Fayerweather. H=Havermeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF MINES

COURSE IN MINING ENGINEERING, 1910-1911

NOTE: See Uniform Curriculum for First Class.

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Chem. 81-82. 309 H	C. E. 23. 306 E Chem. 66. 301 E	Chem. 81-82. 309 H	Phys. 5. 301 E E. E. 2. 301 E	Chem. 81-82. 309 H	C. E. 23. 402 E Chem. 66. 301 E
	10—11	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Phys. 5. 301 E E. E. 2. 301 E
	11—12	Mineral. 1. 516 S Geol. 6. 401 S	Mineral. 1. 516 S Geol. 6. 401 S	Mineral. 1. 516 S Geol. 6. 401 S	Mineral. 1. 516 S Geol. 6. 401 S	Mineral. 1. 516 S Geol. 6. 401 S	Mineral. 1. 516 S Geol. 6. 401 S
	1—2	Dft. 7. 410 E			Chem. 66. 311, 511 H		
	1—4	Dft. 7. 607 E Chem. 66, Lab. 504 H	C. E. 23. 402 E Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	
	4 5		Phys. Ed. B, Gym.			Phys. Ed. B, Gym.	
Third Class	9—10	Min'g 51. 302 M E. E. 4. 301 E	Mech. E. 13. 309 H Mech. E. 14. 309 H	Min'g 51. 302 M E. E. 4. 301 E	Mech. E. 13. 309 H Mech. E. 14. 309 H	Min'g 51. 302 M Me.E.76Lab.Sec.III,IV.WV E. E. 72, Lab. Sec. I, VI. 201 E	Mech. E. 17. 309 H C. E. 64. 402 E
	10—11	Mech. E. 13. 410 E Min'g 52. 302 M	Geol. 105. 401 S Geol. 106. 401 S	Mech. E. 17. 410 E Min'g 52. 302 M	Geol. 105. 401 S Geol. 106. 401 S	Chem. 69. 301 H Me.E.76Lab.Sec.III,IV.WV E. E. 72, Lab. Sec. I, VI. 201 E	Geol. 105. 401 S Geol. 106. 401 S
	11—12	C. E. 53. 301 E Mech. E. 76. 410 E	C. E. 53. 301 E Min'g 54. 302 M	C. E. 53. 301 E Mech. E. 14. 410 E	C. E. 53. 301 E Min'g 54. 302 M	C. E. 53. 301 E Me.E.76Lab.Sec.III,IV.WV E. E. 72, Lab. Sec. I, VI. 201 E	Min'g 54. 302 M
	1—2	Chem. 69. Sec. I. 301 H			Chem. 69. Sec. II. 301 H		
	1—4 Div. A	Chem. 69, Lab. 107 H Mech.E.76,Lab.Sec.I,II.WV	Chem. 69, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 401 S	Chem. 69, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	C. E. 53, Lab. 308 E E.E.72,Lab. Sec.II,III.201 E	C. E. 53. 301 E C. E. 54. 402 E	§C. E. 53, Lab. 308 E C. E. 64, Lab. 510 E
	1—4 Div. B	C. E. 53. 301 E C. E. 54. 402 E	§C. E. 53, Lab. 308 E E.E. 72, Lab. Sec.IV,V. 201 E	C. E. 53, Lab. 308 E Mech. E. 76, Lab. Sec. V, VI, WV	Chem. 69, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Chem. 69, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Chem. 69, Lab. 107 H C. E. 64, Lab. 510 E
Fourth Class	9—10	Met. 101, 111. 306 M Min'g 72. 302 M	Min'g 91. 302 M Min'g 56. 302 M	Met. 101, 111. 306 M Min'g 72. 302 M	Min'g 91. 302 M Min'g 56. 302 M	Met. 101, 111. 306 M Min'g 72. 302 M	Met. 131. 141. 306 M Min'g 56. 302 M
	10—11	Min'g 71. 302 M Geol. 110. 401 S	Min'g 80. 302 M	Min'g 71. 302 M Geol. 110. 401 S	Min'g 73. 302 M Mech. E. 74. 410 E	Min'g 71. 302 M Min'g 94. 301 M	Min'g 81. 302 M Mech. E. 74. 410 E
	11—12	E. E. 75. 302 E Met. 122. 306 M	Min'g 81. 302 M C. E. 76. 301 E	Met. 122. 306 M	Min'g 81. 302 M C. E. 76. 301 E	Mech. E. 17. 301 M Met. 122. 306 M	Min'g 81. 302 M Min'g 94. 301 M
	1—2				Met. 131, 141. 306 M		
	1—4	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Mining 82. 201 M **Met. 72. 401 M §§Min'g 78	E. E. 75. Sec. 1. 202 E *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	E. E. 75, Lab. Sec. II. 202 E *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78

*Three weeks consecutive afternoons. **Ten consecutive afternoons. †During February and March. ‡During April and May. §As assigned. §§Afternoons not otherwise employed. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

SCHOOL OF ENGINEERING

COURSE IN SANITARY ENGINEERING, 1910-1911

NOTE: See Uniform Curriculum for First Class

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Mineral. 5. 516 S Chem. 82. 309 H	Mech. E. 13-14. 309 H	C. E. 21. 402 E Chem. 82. 309 H	Mech. E. 13-14. 309 H	C. E. 21. 402 E Chem. 82. 309 H	Bot. 7. 505 S Mech. E. 14. 410 E
	10—11	Phys. 5. 301 E E. E. 2. 301 E	†Geol. 18. 305 S	Phys. 5. 301 E E. E. 2. 301 E	Chem. 65. 511 H Met. 134. 306 M	Mineral. 5. 516 S †Geol. 18. 401 S	Chem. 65. 511 H †Geol. 18. 305 S
	11—12	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Math. 65. 202, 203, 213, 214 Hm Mech. 102. 506, 609, 613 F, 717 Hm	Mech. E. 13. 301 E Met. 134. 306 M
	1—2		Dft. 5. 306 E			Dft. 8. 306 E	
	1—4	Mineral. 5, Lab. 106 S Phys. 44, Lab. 408 F	Dft. 5. 601 E Sh. Wk. 16, Lab. 125 T	Bot. 7. 502 S Dft. 8. 601 E	Dft. 5. 601 E Phys. 44, Lab. 408 F	Chem. 65, Lab. 504 H Dft. 8. 601 E	Chem. 65, Lab. 504 H ††Chem. 92a †Geol. 18, Lab. and fieldw'k
	4—5	Phys. Ed. B, Gym.		Phys. Ed. B, Gym.			
Third Class	9—10	Zool. 7. 505 S Bact. 101 E. E. 4. 301 E	Chem. 41. 413 H Mech. E. 78. 510 E	C. E. 59. 306 E E. E. 4. 301 E	C. E. 61. 306 E Mech. E. 78. 510 E	C. E. 59. 306 E	Chem. 41 42. 413 H
	10—11	C. E. 53. 306, 402 E C. E. 58. 402 E	C. E. 53. 306, 402 E C. E. 52. 402 E	C. E. 53. 306, 402 E C. E. 58. 402 E	C. E. 53. 306, 402 E C. E. 52. 402 E	C. E. 53. 306, 402 E C. E. 58. 402 E	Zool. 7. 505 S Bact. 101 C. E. 52. 402 E
	11—12	Ast. 105. 604 F Chem. 42. 413 H	C. E. 51. 402 E	Ast. 105-106. 604 F	C. E. 51. 402 E C. E. 62. 301 M	Ast. 105. 604 F Mech. E. 78. 510 E	C. E. 61. 402 E C. E. 62. 301 E
	1—4	Zool. 7 Bact. 101 C. E. 54. 402 E	Zool. 7 Bact. 101 C. E. 58. 406 E	*C. E. 61. 406 E **C. E. 59, Lab. Ast. 106. 604 F	C. E. 51. 402 E C. E. 52. 402 E	C. E. 53. 301 E E. E. 72. 201 E	C. E. 53, Lab. C. E. 62. 406 E
Fourth Class	9—10	C. E. 57, a & b. 306 E C. E. 94. 410 E	C. E. 87. 402 E Mech. E. 76. 306 E	C. E. 94. 410 E	C. E. 87. 402 E C. E. 96. 306 E	Mech. E. 17. 302 E C. E. 96. 306 E	Mech. E. 17. 309 H E. E. 76. 301 H
	10—11	C. E. 75. 302 E C. E. 98. 302 E	C. E. 89. 301 E C. E. 100	C. E. 75. 302 E C. E. 98. 302 E	C. E. 89. 301 E C. E. 100	C. E. 57, *a* and *b*. 302 E C. E. 100	C. E. 89. 306 E C. E. 96. 302 M
	11—12	C. E. 85. 402 E Mech. E. 82. 306 E	C. E. 75. 302 E C. E. 90. 402 E	C. E. 85. 402 E Mech. E. 82. 306 E	C. E. 95. 301 M C. E. 90. 402 E	C. E. 75. 302 E Mech. E. 82. 306 E	C. E. 95. 301 M C. E. 90. 402 E
	1—4	C. E. 55 Mech. E. 76, Lab. WV	C. E. 89. 404 E C. E. 90. 404 E	C. E. 55 C. E. 100	C. E. 87. 404 E C. E. 100	C. E. 85. 404 E E. E. 76. 202 E	Mech. E. 63, Lab. WV

*Except two afternoons in January. **Two afternoons in January. ††Chemistry 92*a*, February and March; †Geology 18, April and May. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

GENERAL INFORMATION REGARDING COLUMBIA UNIVERSITY

Students under the Faculty of Applied Science may enjoy every advantage to be derived from the resources of the University. The University occupies thirty-five buildings, and its grounds cover thirty-five acres. The number of officers of instruction in 1908-9 was 628, and of resident students 5,633.

University Library The Library contains about 400,000 bound volumes, catalogued both by authors and by subjects. It is open each week day from 8.30 A.M. until 11 P.M. (in summer, 10 P.M.). All students and graduates have free access and may draw books for home use.

Physical Exercise The Gymnasium is open each week day from 9.30 A.M. to 7 P.M. (Saturdays, 6 P.M.).

Every student is entitled to a physical examination by the Medical Director and to advice as to the kind and amount of exercise best adapted to his needs. For the Gymnasium fee see page 18.

The main exercising room is 35 feet high, semicircular in shape, and has an area of 16,000 square feet. It is well lighted and well ventilated. Above are the 10-lap running track, rooms for fencing, boxing, and handball, dressing-rooms with 1,804 steel lockers, and 32 shower-baths. Below the exercising room is the semicircular swimming pool, 100 feet by 50, and 4 to 10 feet deep, and shower-, needle-, and tub-baths.

A two-hour course in Physical Education is prescribed for all first and second year undergraduate students, arranged with a view to securing: first, health; second, strength, control, efficiency, and endurance; third, erect carriage.

There are on South Field a practice field for baseball, lacrosse, and football, a quarter mile running track, tennis courts, and the University Boat House is within easy reach.

Employment Committee The Employment Committee endeavors to give students who need it the opportunity to earn enough for partial or complete support, and to extend assistance in other ways. Communications should be addressed to the Committee. Some of the openings available are: private tutoring, translating, addressing, copying of various sorts, teaching in evening schools, stenography. During the year 1908-9 the student earnings reported to the Committee amounted to $100,223.

Preference is naturally given, in case of a choice of applicants, to

those who, as strangers in New York, are not likely to hear of positions through other channels. No prospective student should come to Columbia expecting to depend entirely or even largely upon the assistance of the Committee, and every student should be prepared to meet at least the expenses of the first half-year—say $250.

The chiefs of clinic in the Medical School give advice without charge to students on the lists of the Committee.

There are also Appointment Committees whose duty it is to recommend graduates for teaching or other positions in colleges and universities and to assist competent men to obtain such positions.

Medical Visitor A University Medical Visitor renders medical assistance to students without family physicians in New York for a remuneration to be arranged between himself and individual patients. The medical visitor is Dr. D. S. D. Jessup, office hours 5 to 6 daily, at 542 West 112th Street (telephone, 6382 Morningside).

Residence Halls There are two University dormitories on South Field, with accommodations for 500 men: Hartley Hall, a memorial to the late Marcellus Hartley, and Livingston Hall, named in memory of Robert R. Livingston, of the class of 1765. Each building is 137 feet by 60 and 10 stories high. They have electric light, steam heat, telephones, elevator and shower baths.

The two Halls contain 600 outside rooms, both single and double, which may be rented singly or in suites. The bedrooms average 8 feet by 14.6, and the studies 10 by 14.6. All are 9 feet high. Each bedroom has a clothes-closet and an enamelled basin with hot and cold water, and is provided with heavy oak furniture.

The entrance to each building faces the campus, and leads directly into an assembly room 60 feet square. This room runs up through two stories and has a large open fireplace opposite the entrance.

The weekly charge for a single room ranges from $2.60 to $4.75 for the academic year of thirty-nine weeks. A pamphlet with floor plans and rental charges and containing the Hall Regulations may be had upon application to the Secretary of the University. Rooms will be assigned in the order of receipt of applications, which should be made on a blank provided by the Superintendent of Buildings and Grounds.

University Commons The University Commons (under student management) for the accommodation of the men living in the Residence Halls is conducted upon a system combining *table d'hôte* and *à la carte*. The Commons, which has accommodations for 450 men, is in University Hall, and is open daily from 7.30 A.M. to 7 P.M. There is also a large buffet lunch room.

Other Accommodations Besides the dormitories and the Greek Letter Society club-houses there are many good boarding-houses and apartments near the University, a card-catalogue of which is kept at Earl Hall.

Public Lectures, etc. In addition to the regular courses of instruction, numerous public lectures are given at the University, ordinarily by persons of distinction who are not members of the teaching staff. The University maintains close relations with the other educational and public institutions of the city, and students enjoy unusual privileges at them. Students are also frequently given the opportunity to enjoy important dramatic and musical performances at a considerably reduced cost. For details see the University Catalogue for 1908-09, pages 40-43.

St. Paul's Chapel St. Paul's Chapel, the gift of Olivia Egleston Phelps Stokes and Caroline Phelps Stokes, as a memorial to their parents, is a beautiful cruciform building with 1,050 sittings. Service, at which attendance is voluntary, is held every week-day except Wednesday and Saturday, at noon, the period from 12 to 12.20 being set apart by the University for religious exercises; on Wednesday afternoons at 5.10; and on Sunday afternoons at 4 P.M. There are also frequent organ recitals.

Earl Hall Earl Hall, the home of the religious, philanthropic, and social organizations and interests, is open to all students, without expense, from 8.30 A.M. to 10 P.M. daily, under the management of its Secretary, who is also Secretary of the University Young Men's Christian Association. Provision for the meetings of student organizations is made in the following order: Societies the purpose of which is (1) primarily religious; (2) primarily philanthropic; (3) primarily literary; and (4) miscellaneous student organizations. In 1907-08, 1,117 student meetings were held in Earl Hall. The building is also much used as a general student club house.

Student Organizations The various student organizations, while self-governing, are subject to the following regulations: The schedules of public contests and performances must be approved by a University Committee; budgets for expenditure are approved and checked by the Comptroller of Student Organizations; the University Committee on Athletics, consisting of three graduates, two students and two University officers, adopt and administer rules of eligibility not involving questions of scholarship and govern participation in inter-collegiate athletics. A pamphlet containing the full regulations may be obtained from the Secretary of the University.

The Degree of A.M. A college graduate who completes with marked distinction one of the regular professional courses may be recommended for the degree of Master of Arts if, while pursuing his professional course, he shall have taken additional work, under the Faculty of Pure Science, Philosophy or Political Science, to the extent of a major subject, and have presented a satisfactory essay upon an assigned topic. A detailed statement of the requirements for this degree and also for the Ph.D., with a list of subjects which may be offered, will be found in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science.* See also page 21.

Fellowships For information as to the fourteen University Fellowships of the annual value of $650 each, and the several endowed fellowships open to qualified candidates for the degree of Master of Arts and Doctor of Philosophy, see the *Announcement of the Faculties of Political Science, Philosophy, and Pure Science,* or the University Catalogue.

The three following are of particular interest to students of Mines, Engineering and Chemistry, who are advised to familiarize themselves with the special regulations governing them:

The Tyndall Fellowship for the Encouragement of Research in Physics, endowed by Professor John Tyndall, and of an annual value of $648; the Barnard Fellowship for Encouraging Scientific Research, endowed by the bequest of the late President Barnard, annual value $500, and the Ernest Kempton Adams Research Fellowship, founded by Mr. Edward Dean Adams in memory of his son, Ernest Kempton Adams, annual value $1,250.

Students

In 1909-10 the registration in the Schools of Mines, Engineering and Chemistry is as follows:

First-year class	223
Second-year class	217
Third-year class	151
Fourth-year class	66
Non-matriculated	29
Students from Columbia College	11
Total	697

Of students registered, 104 already held a college or technical degree, representing 38 institutions. In addition there are registered under the Faculty of Pure Science as candidates for the A.M. and Ph.D. degrees 16 students with some branch of Engineering and 28 with Chemistry as a major subject.

ALUMNI ORGANIZATIONS

The Alumni Association of the Schools of Science of Columbia University includes in its membership graduates of the Schools of Mines, Engineering and Chemistry. Associate membership is open to non-graduates, members of classes that have graduated.

Honorary membership is open to all persons eminent in Science who are or have been connected with any of the Schools of Science of Columbia University.

Its officers for 1909-10 are:

President, Daniel E. Moran, C.E., '84.

Vice-President, Arthur S. Dwight, E.M., '85.

Treasurer, Wm. Fellowes Morgan, A.B., E.M., '84.

Secretary, Ralph E. Mayer, C.E., '79.

Board of Managers

E. P. Casey, C.E., '86
H. S. Kissam, Ph.B., '86
K. E. Eilers, E.M., '89
E. Merz, E.M., '92
F. B. Irvine, C.E., '02
J. F. Thompson, Ph.D., '03
J. B. Spencer, M.E., '06
A. Aigeltinger, E.E., '07

Delegates to Alumni Council

Wm. Fellowes Morgan, A.B., E.M., '84
Charles B. Going, Ph.B., '82
George H. Clark, C.E., '93

A complete list of the Alumni, giving the addresses of each, and in the case of those who are members of the Association, a detailed record of their professional career, is published and may be had on application to the Alumni Secretary, Columbia University.

The Alumni Secretary will also be glad to put prospective students in communication with Alumni in different parts of the country.

Such Alumni are often able in a personal interview to furnish information regarding the Schools of Mines, Engineering and Chemistry which inquirers at a distance could obtain in no other way.

GENERAL ALUMNI ORGANIZATIONS

Alumni Council:

John Howard Van Amringe, '60, Chairman
Rudolf Tombo, Jr., '98, A.M., Secretary, Columbia University

Society of the Early Eighties:
James Duane Livingston, '80, President
Gerard Romaine, '82, Secretary, 68 Broad Street, New York City

Society of Older Graduates:
John Howard Van Amringe, '60, President
William de L. Benedict, '74 S, Secretary, 43 Cedar Street, New York City.

Society of Upper Eighties:
Charles H. Mapes, '85, President
Edward L. Dodge, '88 S, Secretary, Columbia University Club, New York City

Local Association Secretaries

Albany—E. Stagg Whitin, '05, University Club, Albany N. Y.

California—Dr. John C. Spencer, '82, '85 M., Butler Building, San Francisco, Cal.

China—Dr. F. E. Hinckley, '05 Ph.D., clerk, United States Court for China, Shanghai, China.

Colorado—Roger W. Toll, '06 S., 215 East Eleventh Avenue, Denver, Colorado.

Columbia (Missouri)—E. W. Hinton, '91 L., Columbia, Mo.

Connecticut—John D. Irving, '96, Yale University, New Haven Conn.

Cuba—Dr. Pedro Villoldo, '05 M., Pena Pobro 20, Havana, Cuba.

District of Columbia—George Oakley Totten, Jr., '91 F. A., 808 Seventeenth Street, N. W., Washington, D. C.

Illinois—Channing Rust Toy, '04, 153 La Salle Street, Chicago, Ill.

Indiana—Mark H. Miller, '07 L., Lemcke Building, Indianapolis, Indiana.

Japan—Rev. Kentok Hori, '07 A. M., College of Literature, Imperial University of Tokio, Tokio, Japan.

Kansas City—David M. Proctor, '05 L., 431 Scarritt Building, Kansas City, Mo.

Kentucky—F. A. Busse, '03 S., 800 Third Street, Louisville, Ky.

Louisiana—Leslie Brewer Smith, '05, 6024 Hurst Street, New Orleans, La.

Madison (Wisconsin)—C. W. Stoddart, '00, University of Wisconsin, Madison, Wis.

Michigan—Dr. Theodore A. McGraw, Jr., '02 M., 73 Cass Street, Detroit, Michigan.

Minnesota—Professor Norman Wilde, '89, University of Minnesota, Minneapolis, Minn.

Nashville—Eugene Tavenner, '01, Peabody College, Nashville, Tenn.

Nebraska—Dr. C. W. Pollard, '99 M., Paxton Block, Omaha, Neb.

New England—Franklin S. Hoyt, '05 A.M., care Houghton Mifflin and Company, 4 Park Street, Boston, Mass.

New Jersey—Arthur F. Egner, '03, Prudential Building, Newark, N. J.

North Carolina—Henry J. Highsmith, T.C., Wake Forest College, Wake Forest, N. C.

Northeastern Pennsylvania—Clarence D. Shrady, '95 S., Allentown, Pa.

Ohio, Northern (Cleveland)—R. H. Johnston, '02, 842 East Seventy-ninth Street, Cleveland, Ohio

Ohio, Central (Columbus)—Professor F. P. Graves, '90, Ohio State University, Columbus, Ohio.

Paris—Charles F. Beach, Jr., '81 L., 95 rue des Petits-Champs, Paris, France.

Philadelphia—Stanley Kidder Wilson, '02, Swarthmore, Pennsylvania.

Pittsburg—Forrest A. DeGraff, '06 T.C., Allegheny Preparatory School, Allegheny, Pa.

St. Louis—William E. Baird, '02 L., Law Department, City Hall, St. Louis, Mo.

Virginia—Jackson Davis, '08 A.M., Board of Examiners, Petersburg, Va.

Washington—Dr. Guy S. Peterkin, '95 M., Alaska Building, Seattle, Washington.

Western New York—E. Lyman Tilden, '02 L., Mutual Life Building, Buffalo, N. Y.

Wisconsin—H. W. Buemming, '95 F.A., 521 Jackson Street, Milwaukee, Wisconsin.

Yonkers—James F. Prince, '08, 87 N. Broadway, Yonkers, N. Y.

Academic Calendar

1910-1911

1910—July 6, Wednesday. Eleventh Summer Session opens.

August 17, Wednesday. Eleventh Summer Session closes.

September 3, Saturday. Last day for filing applications for entrance examinations.

September 19, Monday. Entrance examinations, and examinations for deficient and debarred students begin.

September 21, Wednesday. Registration begins.

September 27, Tuesday. Registration ceases for students previously matriculated. Later applications received only upon payment of an additional fee of $5.

September 28, Wednesday. First half-year, 157th year, begins.

Registration ceases for students matriculating for the first time. Later applications received only upon payment of an additional fee of $5.

Scholars report to the Registrar.

November 8, Tuesday. Election day, holiday.

November 24, Thursday, to November 26, Saturday, inclusive. Thanksgiving holidays.

December 21, Wednesday, to January 3, 1911, Tuesday, inclusive. Christmas holidays.

1911—January 2, Monday. Last day for filing applications for entrance examinations.

January 9, Monday. Mid-year entrance examinations begin.

January 25, Wednesday. Mid-year examinations begin.

February 7, Tuesday. First half-year ends.

February 8, Wednesday. Second half-year begins.

Registration ceases for students entering the second half-year. Later applications received only upon the payment of an additional fee of $5.

Scholars to report to Registrar.

February 13, Monday. Alumni Day.

February 22, Wednesday. Washington's Birthday, holiday.

April 13, Thursday, to April 17, Monday, inclusive, Easter holidays.

May 1, Monday. Last day for filing applications for scholarships.

May 22, Monday. Final examinations begin.

May 30, Tuesday, Memorial Day, holiday.

June 4, Sunday. Baccalaureate service.

June 5, Monday. Class Day.

June 7, Wednesday. Commencement Day.

June 14, Wednesday. Second half-year ends.

June 19, Monday. Entrance examinations begin.

July 6, Thursday. Twelfth Summer Session opens.

August 17, Thursday. Twelfth Summer Session closes.

September 18, Monday. Entrance examinations, and examinations for deficient and debarred students begin.

September 20, Wednesday. Registration begins.

September 26, Tuesday. Registration ceases for students previously matriculated. Later applications received only upon payment of an additional fee of $5.

September 27, Wednesday. First half-year, 158th year, begins.

Registration ceases for students matriculating for the first time. Later applications received only upon payment of an additional fee of $5.

Scholars to report to Registrar.

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Eleventh Series No. 11 April 1, 1911

Columbia University Bulletin of Information

SCHOOLS OF MINES, ENGINEERING AND CHEMISTRY

MINING
METALLURGY
CIVIL ENGINEERING
SANITARY ENGINEERING
ELECTRICAL ENGINEERING
MECHANICAL ENGINEERING
CHEMICAL ENGINEERING
CHEMISTRY

ANNOUNCEMENT

1911-1912

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Columbia University
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New York, N. Y.

Columbia University
Bulletin of Information

(Issued 25 times during the Academic year, monthly in November and December, and weekly between February and June. Entered as second-class matter at the New York, N. Y., Post Office, Dec. 22, 1900, under Act of July 16, 1894.)

These bulletins include:

1. The Report of the President and Treasurer to the Trustees.
2. The Catalogue of the University, issued in December, price 25 cents.
3. The Announcements of the several Colleges, Schools, and Divisions, issued in the Spring, and relating to the work of the next year. These are made as accurate as possible, but the right is reserved to make changes in detail as circumstances require. The current number of any of these Announcements will be sent without charge upon application to the Secretary of the University.

B-10,000 1911

COLUMBIA UNIVERSITY LIBRARY

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THE FACULTY OF APPLIED SCIENCE

Standing Committees of the Faculty

On Instruction. The Dean (Chairman), Professors Kemp, Lovell, Lucke, Walker, Wendell and Whitaker.

On Admissions. Professors Jones (Chairman), Mayer, Morgan and Rautenstrauch.

The Faculty

Nicholas Murray Butler.....*President of the University*
A.B., Columbia, 1882; A.M., 1883; Ph.D., 1884; LL.D., Syracuse, 1898; Tulane, 1901; Johns Hopkins, Princeton, Yale, and University of Pennsylvania, 1902; Chicago, 1903; Manchester and St. Andrew's, 1905; Cambridge, 1907; Williams, 1908; Harvard and Dartmouth, 1909; D.Litt., Oxford, 1905; Officier de la Légion d'Honneur, 1906; Order of the Red Eagle (Prussia), 1910; Member American Academy of Arts and Letters, 1911.

Frederick Arthur Goetze.....*Dean of the Faculty*
M.Sc., Columbia, 1905.

Charles F. Chandler.....*Mitchill Professor Emeritus*
A.M., Ph.D., Göttingen, 1856; M.D., University of New York, 1873; LL.D., Union, 1873; Sc.D., Oxford, 1900.

Henry S. Munroe.....*Professor of Mining, and Delegate to University Council*
E.M., Columbia, 1869; Ph.D., 1876; Sc.D., 1904.

Alfred J. Moses.....*Professor of Mineralogy*
E.M., Columbia, 1882; Ph.D., 1890.

James Furman Kemp.....*Professor of Geology*
A.B., Amherst, 1881; Sc.D., 1906; E.M., Columbia, 1884.

Robert Peele.....*Professor of Mining*
E.M., Columbia, 1883.

William Hallock.....*Professor of Physics*
A.B., Columbia, 1879; Ph.D., Würzburg, 1881; Phar.D., National College of Pharmacy, 1892.

[1]Francis B. Crocker.....*Professor of Electrical Engineering*
E.M., Columbia, 1882; Ph.D., 1895.

Michael Idvorsky Pupin.....*Professor of Electro-Mechanics*
A.B., Columbia, 1883; Sc.D., 1904; Ph.D., Berlin, 1889.

William H. Burr.....*Professor of Civil Engineering*
C.E., Rensselaer Polytechnic, 1872.

Thomas Scott Fiske.....*Professor of Mathematics*
A.B., Columbia, 1885; A.M., 1886; Ph.D., 1888.

Harold Jacoby.....*Rutherfurd Professor of Astronomy*
A.B., Columbia, 1885; Ph.D., 1895.

Henry Marion Howe.....*Professor of Metallurgy*
B.S., Harvard, 1869; A.M., 1872; LL.D., 1905; B.S., Massachusetts Institute of Technology, 1871; LL.D., Lehigh, 1905.

[1]Absent on leave, 1911-12.

EARL B. LOVELL.....*Professor of Civil Engineering*
C.E., Cornell, 1891.

JAMES MACLAY.....*Professor of Mathematics*
C.E., Columbia, 1888; Ph.D., 1899.

MARSTON TAYLOR BOGERT.....*Professor of Organic Chemistry and Delegate to the University Council*
A.B., Columbia, 1890; Ph.B., 1894; LL.D., Clark, 1909.

J. LIVINGSTON RUTGERS MORGAN.....*Professor of Physical Chemistry*
B.S., Rutgers, 1892; A.M. and Ph.D., Leipzig, 1895.

AMADEUS W. GRABAU.....*Professor of Palæontology*
S.B., Massachusetts Institute of Technology, 1896; S.M., Harvard, 1898; S.D., 1900.

RALPH EDWARD MAYER..*Associate Professor of Engineering Draughting*
C.E., Columbia, 1879.

CASSIUS JACKSON KEYSER.....*Adrain Professor of Mathematics*
B.S., Missouri, 1892; A.M., Columbia, 1896; Ph.D., 1901.

GEORGE L. MEYLAN....*Associate Professor of Physical Education and Medical Director of the Gymnasium*
M.D., New York University, 1896; B.S., Harvard, 1902; A.M., Columbia, 1904.

LEA MCILVAINE LUQUER.....*Assistant Professor of Mineralogy*
C.E., Columbia, 1887; Ph.D., 1894.

HENRY CLAPP SHERMAN.....*Professor of Food Chemistry*
B.S., Maryland Agricultural College, 1893; A.M., Columbia, 1896; Ph.D., 1897.

ALBERT P. WILLS.....*Professor of Mathematical Physics*
B.E.E., Tufts, 1894; Ph.D., Clark, 1897.

SAMUEL A. TUCKER.....*Assistant Professor of Electro-Chemistry*
Ph.B., Columbia, 1895.

ADOLPH BLACK.....*Assistant Professor of Civil Engineering*
C.E., Columbia, 1894.

CHARLES EDWARD LUCKE.....*Professor of Mechanical Engineering*
B.S., College of the City of New York, 1895; M.S., New York University, 1899; Ph.D., Columbia, 1902.

WALTER RAUTENSTRAUCH.....*Professor of Mechanical Engineering*
B.S., Missouri, 1902; M.S., University of Maine, 1903.

WILLIAM CAMPBELL.....*Associate Professor of Metallurgy*
B.Sc., Durham University, 1898; D.Sc., 1905; M.Sc., Royal School of Mines, 1903; Ph.D., Columbia, 1903; A.M., 1905.

EDWARD LAWRENCE KURTZ.....*Assistant Professor of Mining*
E.M., Columbia, 1893.

CARLTON CLARENCE CURTIS.....*Associate Professor of Botany*
A.B.,Syracuse, 1889; Ph.D., 1893; A.M., Columbia, 1892.

S. ALFRED MITCHELL.....*Assistant Professor of Astronomy*
A.M., Queens, 1894; Ph.D., Johns Hopkins, 1898.

ARTHUR L. WALKER.....*Professor of Metallurgy*
E.M., Columbia, 1883.

George Braxton Pegram.....*Assistant Professor of Physics*
A.B., Trinity College (N. C.), 1895; Ph.D., Columbia, 1903.

Bergen Davis.....*Assistant Professor of Physics*
B.S., Rutgers, 1896; A.M., Columbia, 1900; Ph.D., 1901.

Adam Leroy Jones.....*Chairman of Committee on Undergraduate Admissions and Secretary of the Faculty*
A.B., Williams, 1895; Ph.D., Columbia, 1898.

Charles H. Burnside.....*Assistant Professor of Mechanics*
B.S., Columbia, 1898; A.M., 1899.

Morton Arendt.....*Assistant Professor of Electrical Engineering*
E.E., Columbia, 1898.

Charles P. Berkey.....*Assistant Professor of Geology*
B.S., Minnesota, 1892; M.S., 1893; Ph.D., 1897.

John Harold Morecroft..*Assistant Professor of Electrical Engineering*
E.E., Syracuse, 1904; B.S., 1907.

W. Benjamin Fite.....*Professor of Mathematics*
Ph.B., Cornell, 1892.

Herbert E. Hawkes.....*Professor of Mathematics*
A.B., Yale, 1896; Ph.D., 1900.

Percy Hodge.....*Assistant Professor of Mechanics*
A.B., Western Reserve, 1892; B.S., Case School of Applied Science, 1894; Ph.D., Cornell, 1908.

Walter Irvine Slichter.....*Professor of Electrical Engineering*
E.E., Columbia, 1896.

George V. Wendell.....*Professor of Physics*
B.S., Massachusetts Institute of Technology, 1892; Ph.D., Leipzig, 1898.

Milton C. Whitaker.....*Professor of Engineering Chemistry*
B.S., Colorado, 1897; M.S., 1899.

J. Paul Jones Williams....*Assistant Professor of Civil Engineering*
B.S., Pennsylvania, 1898; M.S., 1899; C.E., 1908.

Everett J. Hall.....*Assistant Professor of Assaying*

Floyd J. Metzger.....*Assistant Professor of Analytical Chemistry*
Ph.B., Buchtel, 1899; Ph.D., Columbia, 1902.

Harry L. Parr.....*Assistant Professor of Mechanical Engineering*
A.B., Columbia, 1902; Mech.E., 1904.

Samuel Osgood Miller.....*Assistant Professor of Drawing*
C.E., Columbia, 1895.

Edward F. Kern.....*Assistant Professor of Metallurgy*
B.S., Tennessee, 1897; Ph.D., Columbia, 1901.

Hal T. Beans.....*Assistant Professor of Chemistry*
B.S., Nebraska, 1899; A.M., 1900; Ph.D., Columbia, 1904.

Charles W. Thomas..*Assistant Professor of Mechanical Engineering*
Mech.E., Stevens Institute, 1884.

Alexander Smith.....*Professor of Chemistry*
B.S., Edinburgh, 1886; Ph.D., Munich, 1889.

Other Officers

EDWIN R. A. SELIGMAN....*McVickar Professor of Political Economy*
A.B., Columbia, 1879; A.M., 1883; Ph.D. and LL.B., 1884; LL.D., 1904.

GEORGE W. KIRCHWEY.....*Kent Professor of Law*
A.B., Yale, 1877; LL.D., Yale, University of Cincinnati, and New York University, 1908.

HENRY ROGERS SEAGER.....*Professor of Political Economy*
Ph.B., Michigan, 1890; Ph.D., Pennsylvania, 1894.

Instructors

CHARLES C. TROWBRIDGE.....*Instructor in Physics*
B.S., Trinity (Ct.), 1892; M.S., 1903; Sc.D., 1908.

EDWARD K. JUDD.....*Instructor in Mining*
A.B., Williams, 1901; E.M., Columbia, 1904.

THOMAS H. HARRINGTON.....*Instructor in Drawing*
C.E., Columbia, 1889.

LEIGHTON B. MORSE.....*Instructor in Physics*
Ph.B., Iowa College, 1903; Ph.D., Columbia, 1908.

THOMAS McC. GUNN.....*Instructor in Mechanical Engineering*
A.B., Univ. of Washington, 1899; A.M., 1900.

HAROLD W. WEBB.....*Instructor in Physics*
A.B., Columbia, 1905; Ph.D., 1909.

CAVALIER HARGRAVE JOÜET.....*Instructor in Analytical Chemistry*
Ph.B., Columbia, 1882; Ph.D., 1894.

ARTHUR COLON NEISH.....*Instructor in Chemistry*
A.B., Queen's University, 1898: A.M., Columbia, 1900; Ph.D., 1904.

MAURICE A. LAMME.....*Instructor in Mineralogy*
B.S., Montana Agricultural College, 1903; A.M., Columbia, 1904; Ph.D., 1909.

LEWIS P. SICELOFF.....*Instructor in Mathematics*
A.B., Central College, 1900.

OTTO KRESS.....*Instructor in Chemistry*
B.S., Columbia, 1906; A.M., 1907; Ph.D., 1909.

CHESTER A. DARLING.....*Instructor in Botany*
A.B., Albion, 1904; A.M., 1906; Ph.D., Columbia, 1909.

JOHN M. NELSON.....*Instructor in Organic Chemistry*
B.S., Nebraska, 1901; Ph.D., Columbia, 1907.

HERMON W. FARWELL.....*Instructor in Physics*
A.B., Dartmouth, 1902; A.M., 1906.

HARRY W. REDDICK..... *Instructor in Mathematics*
A.B., Indiana, 1904; A.M., Illinois. 1906.

EDWARD D. THURSTON, JR.....*Instructor in Mechanical Engineering*
A.B., Columbia, 1905; Mech.E., 1907.

FREDERICK W. HEHRE.....*Instructor in Electrical Engineering*
E.E., Columbia, 1908.

WILLIAM C. MOORE.....*Instructor in Analytical Chemistry*
B.S., Peabody, 1903.

J. ENRIQUE ZANETTI.....*Instructor in Analytical Chemistry*
B.S., Harvard, 1906; A.M., 1907; Ph.D., 1909.

James S. Macgregor.....*Instructor in Civil Engineering*
B.S., Mass. Inst. of Technology, 1902; M.S., 1904.

James Kip Finch.....*Instructor in Civil Engineering*
C.E., Columbia, 1906.

Arthur Lowell Herrick.....*Instructor in Mechanical Engineering*
B.S., Dartmouth, 1909; C.E., Wisconsin, 1910.

Nels J. Lennes.....*Instructor in Mathematics*
S.B., Chicago, 1898; S.M., 1903; Ph.D., 1907.

Lecturers

William S. Day.....*Lecturer in Physics*
A.B., Columbia, 1884; Ph.D., Johns Hopkins, 1897.

Assistants

Willard L. Severinghaus.....*Assistant in Physics*
A.B., German Wallace College, 1904; A.M., 1905.

Gaillard S. Rogers.....*Assistant in Mineralogy*
A.B., Columbia, 1908; A.M., 1909.

Leon E. Pender.....*Assistant in Physics*
A.B., Trinity (N. C.), 1907; A.M., 1908.

William S. Nelms.....*Assistant in Physics*
A.B., Southwestern, 1903; A.M., 1904.

Joseph S. Corbett.....*Assistant in Mathematics*
A.B., Columbia, 1909.

Bernard O. Dodge.....*Assistant in Botany*
Ph.B., Wisconsin, 1909.

James E. Gray.....*Assistant in Mathematics*
A.B., Columbia, 1909.

Jesse E. Hyde.....*Assistant in Palæontology*
A.B., Ohio State University, 1906.

Frank L. Mason.....*Assistant in Electrical Engineering*
E.E., Columbia, 1909.

Andrew W. Jackson.....*Assistant in Physics*
A.B., Oregon, 1907; A.M., 1909.

Jesse E. Beans.....*Assistant in Drawing*

Robert F. McCrackan.....*Assistant in Analytical Chemistry*
B.S., So. Carolina Military Academy, 1903; A.M., Columbia, 1910.

Daniel Dale Condit.....*Assistant in Geology*
A.B., Ohio State, 1909.

Harry L. Fisher.....*Assistant in Organic Chemistry*
A.B., Williams, 1909.

Abraham Gross.....*Assistant in Analytical Chemistry*
Ph.B., Pittsburgh, 1898; Ph.M., 1900; A.M., Columbia, 1910.

Julian C. Hines, Jr.....*Assistant in Physics*
S.B., Univ. of North Carolina, 1905; M.S., 1909.

Edward N. Milliken.....*Assistant in Chemistry*
B.S., Columbia, 1907; A.M., 1910.

Harold Perrine.....*Assistant in Civil Engineering*
A.B., Columbia, 1908; A.M., 1909.

MORTIMER F. SAYRE.....*Assistant in Civil Engineering*
E.M., Columbia, 1907.

FREDERICK W. SCHWARTZ..*Laboratory Assistant in Physical Chemistry*
B.S., Rensselaer Polytechnic, 1905.

GEORGE A. SCOTT.....*Assistant in Physics*
B.S., Wisconsin, 1902.

Non-Resident Lecturers for 1910-1911

ARTHUR S. DWIGHT, E.M.....*Rio Tinto Mines of Spain*
Consulting Mining Engineer.

THOMAS H. LEGGETT, E.M.....*Preliminary Prospecting*
Consulting Engineer.

A. CHESTER BEATTY, E.M.....*The Evaluation of Mines*
The Examination of Mines
Consulting Engineer.

H. N. COVELL, Ph.B.....*Mine Hoisting Machinery*
The Lidgerwood Mfg. Co.

J. D. IRVING, A.M., Ph.D.....*Replacement Ore Deposits*
Professor of Geology, Yale University.

J. W. PAUL, E.M.....*Mine Rescue and First Aid Methods*
In charge of Mine Rescue and Lighting of the Pittsburgh Station of the Bureau of Mines.

NELSON P. LEWIS, C.E.....*The Planning of a Modern City*
Chief Engineer, New York Board of Estimate and Apportionment.

ALFRED NOBLE, C.E.....*The Pennsylvania Tunnels*
Noble & Woodard, Consulting Engineers.

JOHN A. BENSEL, C.E.....
New York State Engineer.

W. J. WILGUS, C.E.....*The Tunnel under the Detroit River*
Former Chief Engineer, New York Central and Hudson River Railroad.

PETER COOPER HEWITT, Ph.D.....*The Mercury Arc Rectifier*
Scientist.

HENRI G. CHATAIN, E.E.....*Gasolene Electric Cars*
General Electric Company.

WALTER E. HOLLAND.....*The Edison Storage Battery*
Edison Storage Battery Company.

J. E. NOEGGERATH, Dr. Ing.....*Acyclic (Unipolar) Generators*
Consulting Engineer.

D. MCFARLAM MOORE.....*The Moore Light*
Vice-President and Chief Engineer, Moore Light Company.

C. W. STONE, E.E.....*Electric Lighting*
General Electric Company.

WILLIAM J. HAMMER.....*Radio-Activity*
Consulting and Supervising Engineer.

J. G. CALLAN.....*Turbo Compressors*
Arthur J. Little Company.

H. G. REIST.....*High Speed Alternators*
General Electric Company.

H. F. T. Erben.....*Turbine Generators*
General Electric Company.

R. H. Rice.....*Turbine Installations*
General Electric Company.

L. C. Loewenstein.....*Turbine Design and Turbo Compressors*
General Electric Company.

Frederick Ray.....*Pumping Machinery*
Alberger Condensor Company.

Robert M. Raymond, E.M.....*El Oro*
El Oro Mining and Refining Co.

Fred Ophuls.....*Refrigerating Machinery*
De La Vergne Machine Company.

Lincoln DeG. Moss.....*Elevating and Conveying Machinery*
Consulting Engineer.

F. E. D. Longacre.....*Air Machinery*
Ingersoll-Rand Company.

Fred J. Miller.....*Shop Processes*
Production Engineer, Remington Typewriter Company.

L. R. Pomeroy.....*Methods of Recording Plant Operation*
J. G. White Company.

Charles B. Going.....*Organization and Management*
Editor, Engineering Magazine.

N. C. Grover.....*Water Power Machinery*
J. G. White Company.

H. J. B. Clarke.....*Steam Power Plant Piping*
Consulting Engineer.

Charles A. King.....*Heating and Ventilating*
With Henry C. Meyer, Consulting Engineer.

Charles U. Carpenter.....*Business Organization*
President, Herring-Hall-Marvin Safe Company.

D. D'A. Ryan.....*Factory Lighting*
General Electric Company.

F. M. Griswold.....*Factory Fire Protection*
Chief Inspector, Home Insurance Company.

F. M. Towl.....*Transmission*
Standard Oil Company.

H. DeB. Parsons.....*Fans and Blowers*
Consulting Engineer.

Walter Clark.....*Shop Processes*
Niles-Bement-Pond Company.

Wilfred Lewis.....*Shop Processes*
Tabor Manufacturing Company.

H. T. Abrams.....*Pumping Water by Compressed Air*
Ingersoll-Rand Company.

S. W. Dudley.....*Air Brakes*
Assistant Chief Engineer, Westinghouse Air Brake Company, Pittsburg, Pa.

Edward Taggart Child, A.M., M.E.....*Blowing Engines*
Southwark Foundry & Machine Co., Philadelphia, Pa.

C. W. Rice.....*Trip of the A. S. M. E. to England*
Secretary, American Society of Mechanical Engineers.

F. B. WHITEMORE.....*The Silent Knight Engine*
Demorest & Co., New York City.

A. S. MASS..*Opportunities for Young Engineers in Power Plant Work*
Chief Engineer, General Electric Company, Schenectady, N. Y.

CARLOS DEZAFRA.....*The United States Navy*
Consulting Engineer, C. H. Seabury & Co., New York.

W. H. WHITE.....*The Oxy-Acetylene Welding*
Business Manager, Nelson Goodyear Company.

A. P. HALLOCK, Ph.D.....*Artificial Mineral Waters*
Chemist, Schultz Mineral Water Company, New York.

H. S. MINER, B.S.....*Rare Earth Industry*
Chief Chemist, Welsbach Company.

ARTHUR H. ELLIOTT, Ph.D.....*Gas*
Consulting Engineer and Chemist to Consolidated Gas Company, New York.

MAXIMILIAN TOCH, Ph.D.....*Paints and Pigments*
Toch Brothers, Paint Manufacturers, New York.

CHARLES F. MCKENNA, Ph.D.....*Cement*
Consulting Chemical Engineer, New York.

DR. LEO H. BAEKELAND.....*Rubber and Plastics*
Consulting Chemist, New York.

C. A. BROWNE, Ph.D.....*Sugar Production*
Chemist in Charge, New York Sugar Trade Laboratory, New York City.

W. D. HORNE, Ph.D.....*Sugar Refining*
Chemist, National Sugar Refining Company.

H. C. HUMPHREYS.....*Starch and Glucose*
Chemist, Corn Products Refining Company.

C. E. NORTH, M.D.....*Sanitary Milk Production*
Consulting Sanitarian, Secretary, New York Dairy Demonstration Company.

ROBERT SCHWARZ, B.S.....*Fermentation Industries*
Fermentation Expert.

DAVID WESSON, Ph.D.....*Some Edible Fats and Oils*
Manager Technical Department, Southern Cotton Oil Company.

H. W. WILEY, Ph.D.....*The Advantages of Chemistry to the Public*
Chief Chemist, Bureau of Chemistry, Department of Agriculture, Washington, D. C.

University Officers of Administration

FRANK DIEHL FACKENTHAL, A.B.....*Secretary of the University*
WILLIAM A. HERVEY, A.M.....*Registrar of the University*
CHARLES S. DANIELSON.....*Bursar*
HENRY L. NORRIS, M.E.....*Superintendent of Buildings and Grounds*
MALCOLM M. ROY, A.B....*Secretary, Committee on Employment for Students*

Chaplain of the University
REV. RAYMOND C. KNOX, B.D.

Medical Director of the Gymnasium
GEORGE L. MEYLAN, M.D.

Secretary of Earl Hall
JAMES MYERS, A.B.

University Medical Visitor
D. STUART DODGE JESSUP, M.D.

INTRODUCTORY

Columbia University was founded in 1754 as King's College. In 1784, after the Revolutionary War, King's College became, by act of the Legislature of the State of New York, Columbia College. The institution whose name was thus changed has become Columbia University.

The first step for the foundation of a Faculty of Applied Science was taken in 1864, when the Trustees approved the creation of a School of Mines, in which courses were later established in civil engineering, chemistry, and metallurgy. The growth of these courses made it seem desirable to adopt some more comprehensive name than the historic title "School of Mines," so that in 1896 the Schools of Engineering and Chemistry were set off from the School of Mines, the three schools remaining, however, under the jurisdiction of a single faculty:

1. The School of Mines, with four-year courses leading to the degrees of Engineer of Mines and of Metallurgical Engineer.

2. The School of Engineering, with four-year courses in Civil Engineering, Sanitary Engineering, Electrical Engineering, and Mechanical Engineering, leading to the degrees of Civil Engineer, Electrical Engineer, and Mechanical Engineer respectively.

3. The School of Chemistry, with four-year courses, leading to the degrees of Chemist and Chemical Engineer.

The courses are intended to meet the requirements of the several professions indicated; and many of them permit a certain amount of specialization, particularly in the fourth year. The work in the School of Mines is so arranged that the student can emphasize the engineering, the metallurgical, or the geological side of his profession.

Candidates for a professional degree who have some special end in view are occasionally permitted to vary the regular course by substituting other courses offered under the Faculty of Applied Science. Students holding an academic degree may become candidates for the degree of Master of Arts or Doctor of Philosophy (see page 23). Non-matriculated students, properly qualified by age, special training and experience and by ability, may sometimes pursue advanced studies of original research.

In the regular Summer Session held at the University in July and August of each year and in the Department of Extension Teaching many courses of assistance to engineering students are offered. The *Announcement of the Summer Session* and the *Announcement of Extension Teaching* will be sent upon application to the Secretary of the University.

ADMISSION

Admission to the Schools of Mines, Engineering and Chemistry is by examination, certificate from approved degree-granting institutions in so far as the certification corresponds specifically with the stated requirements.

Except for reasons of weight, candidates for admission to the first-year class must be at least eighteen years of age at the time of matriculation, and correspondingly older for admission to advanced standing. Each candidate must before admission present a certificate of good moral character from his last teacher or from some citizen of good standing. Students from other colleges or universities must bring certificates of honorable dismissal. Students are admitted subject to the disciplinary powers of the University authorities.

All requests for information regarding admission should be addressed to the Secretary of the University.

Collegiate Preparation Recommended

The liberal training offered by a preliminary Collegiate Course is quite as important to engineers, metallurgists and chemists as to lawyers, physicians or clergymen, and is strongly recommended by the Faculty of Applied Science. This, however, does not and should not involve a residence of eight years in college and technical school before a candidate receives the professional degree.

A graduate of any good college who has selected his course with reference to future work in applied science is able to complete the requirements for a degree in the Schools of Mines, Engineering and Chemistry in less than four years after receiving the Bachelor's degree. The opportunities for close articulation between Columbia College and these Schools are particularly good. Under the provisions of the new program it is possible for a well-prepared student to complete the requirements for both the collegiate and professional degrees in six years.

This six year combined course includes two years College work in English, two years in either French or German and one year each in History and Philosophy, all of these being prescribed for the College degree in addition to the courses included in the professional programs. The necessary total of College credits for the Bachelor's degree is made up by the election of four or more non-technical courses, the exact number depending on the subjects offered for admission. These should include work in Economics and according to the students' own preferences, additional work in English, History, Philosophy or modern languages (Spanish, for example), or work in Latin, Politics, or in some Natural Science not included in the professional program. In general it is better to lay a broad foundation for future professional study than to attempt the anticipation of courses which are later to be dealt with intensively in the professional program.

Under the regulations, a student may either concentrate his collegiate prescriptions and electives in the first two years of residence and then enter the uniform first year of the professional course, or he may dis-

tribute the work of the uniform first year, all of which is non-professional in character, over three years of collegiate residence, and at the beginning of the fourth year, enter the second year of one of the professional courses. The latter plan, which is more likely to insure continuity in the fundamental courses in Mathematics, Physics and Chemistry is, in the judgment of the College Faculty, the more desirable.

Requirements for Admission for Students without Collegiate Preparation

To the First Year Class

Every candidate must offer at the entrance examinations (see below) subjects amounting to fourteen and one-half "units." A unit represents a course of five periods a week for one year in the secondary school.

Total requirement.....14½ units

	Counting in Units
The candidate must offer:	
Chemistry	1
Drawing	1
Elementary French *or* Elementary German	2
English	3
Mathematics	3½
Physics	1
and three units from the following:	
Elementary French *or* Elementary German *see above*	2
Elementary Spanish	2
Elementary Latin	2
Intermediate French	1
Intermediate German	1
Ancient History	1
Modern and Mediæval History	1
American History	1
English History	1
Botany	1
Physiography	1
Zoölogy	1
Shopwork	1

Candidates for degrees of Engineer of Mines, Metallurgical and Chemical Engineer or Chemist, are recommended to offer Elementary and Intermediate German.

It is suggested that candidates deficient in entrance subjects in

June arrange to take courses in them in the Summer Session of Columbia University, the announcement of which will be sent upon application to the Secretary of the University. Certain of the entrance subjects may also be pursued under the Department of Extension Teaching.

The examination requirements for admission may be satisfied by any one of the three following means, or by any approved combination thereof:

Entrance Examinations

1. By the examinations of the College Entrance Examination Board. These examinations are held annually in June, in 1911 beginning on June 19th, at Columbia University and at about one hundred and fifty other educational centers in the United States and Europe. A complete list of the places and times of such examinations, together with the regulations governing them, may be obtained from the Secretary of the College Entrance Examination Board, Post Office Sub-Station 84, New York City.

2. By the examinations conducted by the Columbia University Committee on Undergraduate Admissions. These examinations are held in September and January of each year (beginning on September 18, 1911, and January 15, 1912), and only at the University.

3. By the examinations of the State Examination Board of the New York State Education Department. These examinations are held in January and June at more than six hundred high schools and other institutions throughout the State of New York, but, save in exceptional circumstances, are open only to students in those schools. Full information regarding the regulations governing them may be obtained by application to the New York State Education Department, Albany, New York.

A copy of the time-scheme of the examinations held by the College Entrance Examination Board in June, and by Columbia University in September and January, together with information as to the proper method of filing application-blanks for these examinations, the payment of fees, the division of examinations, and also detailed definitions of the requirements in each admission subject, is given in the *Bulletin of Entrance Examinations and Admission* for 1911, which may be had upon application to the Secretary of the University.

A candidate may present himself at any of the series of examinations scheduled above, and the results may be credited toward the fulfilment of the requirements for admission, subject to the following restrictions:

Restrictions Governing Examinations

1. A candidate in making application for examination must submit a statement from the principal of his school, or from his last instructor, indicating the extent and character of his preparation in each subject in which he applies for examination, and credit may be withheld when this requirement is not met.

2. The results of an examination may stand to the candidate's credit for twenty-nine months, but no longer.

3. A candidate may not present himself for examination more than four times, except by special consent of the Committee on Undergraduate Admissions.

4. The results of the examinations conducted by the New York State Examination Board can be credited only in so far as the subject-matter of these examinations specifically covers the subjects, or lettered or numbered parts of a subject, which are accepted for admission to the Schools of Mines, Engineering and Chemistry. Candidates who have been granted the College Entrance Diploma issued by the New York State Education Department may be admitted to the Schools of Mines, Engineering and Chemistry free of conditions if the directions given on page 8 of the Columbia University *Bulletin of Entrance Examinations and Admission* have been observed. The diploma should be forwarded to the Secretary of the University together with the application for admission.

5. In order to be credited toward entrance, the reports of a candidate's examinations, together with the statement of the extent and character of his preparation in each subject offered, must be in the hands of the Committee on Undergraduate Admissions one week prior to the opening of the term in September or January.

6. The reports of all examinations must be rendered to the Committee on Undergraduate Admissions in percentages. The Committee interprets these percentages as Passed (P), or Failed (F). Credit toward admission is given only for such examinations as receive a grade of P.

To Advanced Standing

The uniform first year in the Schools of Mines, Engineering and Chemistry, and the efficient coördination of the subsequent years, make it possible for graduates of colleges and scientific schools to enter Columbia University with advanced standing and to complete the requirements for a professional degree without undue delay through conflicts and other causes. It is very desirable, however, that students in other colleges who are planning to take professional work after graduation should get into correspondence with the University as early as possible. If this is done they may receive advice with regard to the most advantageous collegiate subjects to elect, and also with regard to the summer courses of Columbia University. By taking certain summer work at the University in advance, a student sometimes may save six months or a year in entering upon his professional career. A separately printed leaflet on admission to advanced standing in these Schools will be sent on application to the Secretary of the University.

Candidates for admission to advanced standing should make application in writing to the Chairman of the Committee on Undergraduate

Admissions in time to reach him on or before September 11, 1911.[1] The application must be accompanied by properly certified official statements of his standing in the subjects which he offers.

The Committee will notify the candidate at the address given in his letter, between September 11 and 15, 1911, what courses, of those offered, are accepted as equivalent to courses at Columbia University. In general, the Committee gives credit for complete courses only.[2] In cases where the work previously done by the candidate has not been accepted by the Committee, the candidate should present himself at regular fall examinations during the two weeks immediately preceding the opening of the University (in 1911, September 18-25). For courses in which no regular fall examination is held, the candidate should report between 10 A.M. and 12 M. at the Dean's office. The schedule of fall examinations may be obtained from the Registrar.

Admission to Special Courses of Study

Graduates of these Schools, and other institutions of equal grade, may pursue any subjects taught in the schools for which they are qualified.

Persons of mature age who are not graduates, but who show special qualifications, are sometimes permitted to pursue special courses of study, but this permission is not given to others.

Except by vote of the Committee on Undergraduate Admissions no one will be admitted as a non-matriculated student who has been refused admission, or has failed in his work, as a candidate for a degree.

Persons who wish merely to pursue elementary subjects are not received as non-matriculated students.

Non-matriculated students will be held to the observance of the same regulations as to attendance, examination and proficiency as matriculated students.

Admission on Probation

Every first-year student admitted conditionally will be held under probation during the first half-year of residence. So far as possible, students on probation are given the opportunity in Columbia College or in the Department of Extension Teaching, to make good their deficiencies. Not later than the end of this period, the Dean, on the basis of reports from the head of each department in which the student is registered, will decide whether he shall be admitted to full standing, have his period of probation extended, or be dropped from the roll. The mark of 7 or higher, obtained in any subject at the end of the first

[1]When the candidate is at a considerable distance from the University, his application should, if possible, be made earlier than September in order that he may receive the reply in time to present himself at the University on September 18, 1911.

[2]In cases where credit for part of a course might be given, the candidate should present his case to the Chairman of the Committee on Undergraduate Admissions, at the times given above, bringing drawings, note-books, or other evidence showing the scope and character of his work.

COLUMBIA UNIVERSITY FROM THE WEST

half-year residence, will be regarded as removing an entrance condition in that subject, unless the condition was incurred in a part of the subject not directly involved in the work of the course. Any condition not so removed must be satisfied by formal examination.

ADVICE TO STUDENTS

Each student is on entrance assigned to an officer of instruction, who acts as his academic adviser. The adviser is kept informed as to the attendance and standing of all such students in their academic work and as to the extent and character of their participation in extracurricular activities, and he advises students on all these and other matters that concern them as students.

Reports of standing are sent to the student, his parent or guardian, his adviser and to the Dean every five weeks for students in the first and second classes and at the end of each term for students in the third and fourth classes.

A student who has not been assigned to an adviser may apply to the Dean for such assignment.

REGISTRATION

Before attending any University exercises each student must register, *i. e.,* must present himself in person to furnish the information necessary for the University records and to file a statement of the courses he is authorized to pursue (for the matriculation or registration fee, payable but once, see below).

The office of the Registrar, 201 East Hall, will be open for registration from Wednesday, September 20, to Tuesday, September 26, 1911. New students may register also on September 27. Credit for attendance will date from September 28.

Students prevented, through no fault of their own, from completing their registration in due time, should file a provisional registration-record.

Registration at a later date is permitted only to candidates who obtain the written consent of the Dean, satisfactory cause for the delay having been shown. (For the fee for late registration see below.)

Students holding scholarships are required to register not later than the date specified in the University calendar; failure to do so may be considered as vacating the scholarship.

Honorable Dismissal

In case of withdrawal during the academic year, students are requested to file a notice thereof with the Registrar, on a blank form provided for the purpose. An honorable dismissal is granted by the Dean to any student in good standing over twenty-one who may desire to withdraw, and, with the written assent of his parent or guardian, to a student under that age. Applications for leave of absence should be addressed to the Dean.

FEES

The President is under instructions to withdraw the privileges of any student delinquent in payment after the second Wednesday of each half-year. All regulations as to fees are subject to change by the Trustees at their discretion.

For Matriculation or Registration: Required of all students on entrance, payable but once..... $5

For late Registration (see above)..... 5

For Tuition in the Schools of Mines, Engineering and Chimistry, payable at the beginning of each half-year: For matriculated students for each half-year..... $125

For non-matriculated students, $7.50 per half-year for each hour of attendance upon lectures and recitations per week; with additional charges for laboratory work up to $25 per half-year when the number of hours weekly of such work does not exceed nine, and of $40 per half-year when the number of hours weekly exceeds nine; the whole not to exceed $125 per half-year.

For the use of the Gymnasium: Required of all students who do not hold an academic degree; optional for students holding such a degree..... 7

For examinations, payable in each case before the examination:

For entrance (see p. 13 *et seq.*)..... 5

For a deficiency examination or series of deficiency examinations held in the week preceding the opening of the first half-year, for each course $5, with a maximum of..... 25

For a deficiency examination at any other time than in the period designated above, whether taken at the conclusion of a course repeated by the student in addition to his normal schedule, or without such repetition, for each course[1]..... 5

For special examinations at unusual times:

For admission, for the series..... 5

For removal of deficiencies in course, for each course..... 5

For any professional degree, payable prior to filing of application[2]..... 25

Laboratory Fees

Students not candidates for a degree, as well as all candidates for the higher degrees, are charged, in addition to the prescribed tuition fee,

[1] This applies to every course in which the student has already received a mark other than passing, whether such mark was reported as a failure, or merely as incomplete.

[2] Refunded to unsuccessful candidates upon application to the Registrar not later than June 20 next ensuing.

a fee for certain laboratory courses and for the use of laboratories, up to a maximum fee of $125 per half-year, including tuition. The schedule of such fees may be obtained from the Registrar.

Summer Courses in Surveying

Laboratory fees, payable on or before the last Saturday in May, are required as follows: Civil Engineering course No. 15, $25, or $7 per survey; No. 25 and No. 27, $15, or $5 per survey; No. 26, $5; No. 28 and No. 71, $10.

Non-candidates, candidates for admission to, and students having entered with advanced standing, who may be required to attend these courses, and students required to repeat them through delinquency, are charged in addition tuition fees as follows: No. 15, $35; No. 25, No. 27, No. 28, and No. 71, $25; No. 26, $10. Students entering with credit for part of course 15 shall pay a tuition fee of $10 for each survey. A tuition fee of $6 is required for each survey of courses 25 or 27 taken under similar conditions. In the case of a student registered in Columbia College who has paid an additional fee under the operation of this rule, an equitable credit will be made should he later complete the requirements for a professional degree. In the case of a student admitted to advanced standing the additional fee may be refunded in whole or in part, according to regulations which may be learned from the Registrar.

Deposits for Apparatus, Supplies and for Keys to Desks and Lockers

A deposit for the use of lockers, keys, apparatus, material, and the like, ranging from $1 to $40, is required of students in Mines, Engineering and Chemistry. At the end of the academic year each student will be credited with those articles which he returns in good order, and the value of those he has injured or broken will be deducted from his deposit. Details may be obtained from the Bursar.

Residence Halls and University Commons

(See page 121)

Employment Committee

(See page 120)

Comparative Statement of Students' Probable Expenses for the Academic Year

	Low	Average	Liberal
Matriculation	$ 5	$ 5	$ 5
Gymnasium	7	7	7
Tuition	250	250	250
Books	30	45	60 up
Drafting material	2	10	15 "
Chemical apparatus	25	30	40 "
Room (37 weeks)	100	129	160 "
Board (37 weeks)	150	180	205 "
Clothes and laundry	100	40	75 "
College incidentals	2	5	25 "
Other expenses	10	25	75 "
Summer Courses in Surveying			
Tuition	25	25	25
Travelling	5	5	5 up
Board (5 weeks)	35	35	35 "
	$646	$791	$982

The expense for summer courses in surveying applies to all curriculums during the first summer only; for Mining and Metallurgical Engineering students during two summers; for Civil and Sanitary Engineering three summers.

RULES GOVERNING STUDENTS

1. A student cannot be a candidate for more than one professional degree at the same time.

2. A candidate for a degree must comply with all requirements in force at the time said degree is conferred.

3. A student will be permitted to substitute one subject for another provided he obtains the consent of the Dean, the heads of departments concerned and the head of the department giving the technical instruction leading to the degree.

4. A student absent from more than one-tenth of the required exercises will be debarred from examination in that subject. No student shall be exempt from this regulation except by action of the Committee on Instruction.

5. After examinations have been held, officers shall send to the Registrar a list of all students who have attended their courses, indicating proficiency by numbers on a scale of 10, a mark below 6 signifying a failure to pass. Reports of standing will be sent to First and Second-year students every five weeks and to the Third and Fourth-year students at the end of each term. Copies of all reports are at the same time sent to the Dean, to the Faculty Adviser and, in the case of First and Second-year students, to the parent or guardian. They will be sent to the parent or guardian of Third and Fourth-year students only on request.

6. Regular examinations shall be held at the end of the first half-year and at the end of the second half-year in all subjects offered during those respective periods. An examination may be held at the completion of any subject which does not extend throughout the given half-year.

7. Special examinations for students deficient at regular examinations shall be held during the two weeks in September preceding the opening of the next following academic year; and for members of the fourth class in subjects belonging to that year only, during the first week in May.

Students who have been debarred are excluded from such examinations in accordance with the terms of the following rule.

Any student who shall have been debarred from any midyear or final examination in any subject shall not be allowed to take a deficiency or make-up examination in said subject until he shall have repeated said course in class.

8. Failure to pass a Summer Session course, credit for which would be accepted as equivalent to a regular undergraduate course in the Schools of Mines, Engineering and Chemistry, shall be counted, in case a student registers for said course, as one of the three failures referred to in Rule 10.

9. The fee for special examinations is $5 for each course, which must

be paid when the application is made. For special examinations in the September series the maximum fee is $25.

10. A student failing to pass in any subject at the regular examinations must present himself for special examination as provided under Rule 7.

Failing to pass the second examination, he must repeat the subject with the next class. Failing a third time to pass a satisfactory examination he may be dropped from the roll of the School.

11. Absence from any regular or special examination provided for in Rules 7 and 8 shall count as a failure unless excused by the Dean for reasons of weight.

12. No student having an entrance deficiency shall be permitted to register for any subject of the second, third or fourth year without the written consent of the Dean, and no student shall be permitted to register for any subject the prerequisites for which have not been satisfied by him unless the Dean, for reasons of weight, grants him special permission.

13. Any student who shall have passed a satisfactory examination in Columbia College in any subject forming a part of one of the professional courses in the Schools of Mines, Engineering and Chemistry will not be required to pursue that subject a second time.

14. During vacations following the close of each year, memoirs on assigned subjects must be prepared by the students in the courses of Mining, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, and Chemistry. The time specified for the completion and handing in of memoirs will be as stated in the respective departmental announcements.

A student failing to hand in his memoir, drawings or other summer work at the time specified by the department in which he is registered shall be considered to have failed; to have his work received later, he will be obliged to pay a fee of $5, as for a special examination.

15. By permission of the Dean, and concurrence of the heads of departments concerned, a student may attend subjects not required for his degree, provided such attendance does not interfere with his regular work. He must fulfill all the requirements exacted from regular students in such course.

Application for each special examination, except as provided below, must be filed at the office of the Registrar at least one week before the examination is to be taken, and in September and May at least one week before the first day of the respective examination period (in 1911-12 not later than Monday, September 11, and Monday, April 22, respectively). For later application an additional fee of $5 for any examination or series of examinations will be charged. Applications must be made on blanks (one for each course) to be obtained from the Registrar.

During the academic year students will be held responsible for the

receipt of reports and other official communications sent to them at the coat room in Havemeyer Hall. During the summer vacation they will be held responsible for the receipt of such communications sent to their home address as given on their registration blank for the preceding academic year.

SCHOLARSHIPS

Fifty-one scholarships of $250 each, payable in semi-annual instalments during the maintenance of a satisfactory grade, are available to students in Mining, Engineering and Chemistry who are in good academic standing, and in need of pecuniary aid. The awards are not based on competitive examinations. Scholars are not exempt from the payment of fees.

Applications for appointment or reappointment should be made on blanks furnished by the Secretary of the University, and filed with him on or before May 1.

Awards will be made not later than July 1 by the Committee on Scholarships. Scholarships not allotted at this time, or becoming vacant, may be filled by the Committee at its discretion.

In detail these Scholarships are as follows:

Open to students who have been in the University at least one year—7 J. Pierpont Morgan, 7 Cornelius Vanderbilt, 10 D. Willis James, 1 Morris K. Jesup, 1 Samuel D. Babcock, 1 Oswald Ottendorfer.

Open to students of any class—8 Faculty, 15 Special, 1 Benjamin B. Lawrence. The Richard Butler scholarship (open to students born in Ohio; for special regulations see University catalogue) has an annual value of $200.

In addition 40 Pulitzer Scholarships, carrying free tuition and a stipend of $250, are open to competition by students in the New York City High Schools. For details see the University catalogue.

Marcus Daly Scholarship in Mining Engineering

The Marcus Daly Scholarship of the annual value of $1,000, maintained by Mrs. James W. Gerard in memory of her father, is open to that worker or descendant of a worker in the Montana mines who passes the best competitive entrance examinations. The winner holds the same throughout his course in mining engineering conditionally upon his maintaining a grade of at least 6.75 in all subjects. The next scheduled competition will be in 1911.

Class of '85 Scholarship

The class of '85 scholarship is open to duly registered students in the Schools of Mines, Engineering and Chemistry, and the holder is entitled to receive the net annual income of the class of '85 School of Mines Scholarship Fund of $7,000. The holder is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science.

MEDALS AND PRIZES

Prize of the New Jersey Alumni Association A prize of $50 is awarded annually by the New Jersey Alumni Association to the New Jersey student who passes the best entrance examinations to the Schools, with the proviso that before the award the student shall complete satisfactorily one half-year of academic work.

Barnard Medal A gold medal valued at $200, endowed by President Barnard, is awarded quinquennially (next award, 1915) on the recommendation of the National Academy of Science to the person who within the five years next preceding shall have made such discovery in physical or astronomical science, or such novel application of science to purposes beneficial to the human race as shall be esteemed most worthy of such honor. For details and for a list of previous awards see the Annual Catalogue of the University.

Illig Medals A bequest of $2,000 by William C. Illig, E.M., '82, provides for the annual award of medals to the student or students in the graduating class of these Schools who shall, in the judgment of the Faculty, have merited the same by commendable proficiency in their regular studies.

Darling Prize A prize in Mechanical Engineering, the income of $1,000, bequeathed by Edward A. Darling, formerly Superintendent of Buildings and Grounds, is awarded annually to the most faithful and deserving student of the graduating class in mechanical engineering, the recipient to be chosen by members of the graduating class in that Course from among three names to be chosen by the Faculty.

OPPORTUNITIES FOR ADVANCED INSTRUCTION AND RESEARCH

Special attention is called to the opportunities offered through the Faculty of Pure Science to men who have received the Bachelor's degree or its equivalent from any recognized college or scientific school for advanced instruction and research in Mining Engineering, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering and Chemistry, leading to the degrees of A.M. and Ph.D. Any of the subjects mentioned above may be offered as a major or minor for either of these degrees. An outline of the courses in these subjects which may be offered toward the higher degrees by candidates who have completed the necessary prerequisites will be found in this announcement (see pp. 80, 86, 101 and 106 *et seq.*), and the general regulations as to graduate work are printed in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science,* which may be had upon application to the Secretary of the University. Ordinarily, the degree of Master of Arts may be obtained after one year's work in residence and the degree of Doctor of Philosophy after three years, the minimum requirement for the latter degree, however, being two years. See also p. 123.

UNIFORM CURRICULUM FOR THE FIRST YEAR

The curriculum for the first year of the four-year courses leading to the degrees of Engineer of Mines, Metallurgical, Civil, Electrical, Mechanical and Chemical Engineer and Chemist is the same in every respect and the student entering the first-year class need not declare which course he will follow until the beginning of the second year, when he will have the advantage of the experience gained during the first year's work, where uncertainty exists respecting inclination or natural bent.

As will be seen in the tabular statement given below, this first year is mainly devoted to a thorough grounding in Mathematics, Physics and Chemistry, the three fundamental subjects which form the indispensable basis for all broad and successful engineering work, not only in the remaining years of the course, but throughout the entire professional career. Specialization begins to some extent in the second year and becomes more marked in the third and fourth years.

The class is arranged in two divisions, Division B completing Engineering Drafting and Descriptive Geometry in the first term, while Division A is completing Qualitative Analysis, the two divisions reversing the operation in the second term. This plan secures greater concentration of work; it facilitates the transfer of students to advanced standing from other institutions; and it enables well-prepared students entering in February and taking advantage of the University Summer Session to catch up with their class by the following autumn.

To secure the most effective individual instruction the class is also divided for quizzes and recitations into six, eight, and in some cases twelve sections.

First Half Year			Hours per week	
See Page			Class	Lab'y
68	Chemistry 3	General Inorganic Chemistry	3	
81	Drafting 1	Engineering Drafting	1	14
81	Drafting 3	Descriptive Geometry	3	
88	Mathematics 1	Algebra	2	
88	Mathematics 3	Analytical Geometry	3	
108	Mechanics, 1	Elementary Mechanics	2	
107	Phys. Educ. A	Gymnasium		2
108	Physics 3	Elementary Mechanics, Properties of Matter and Heat	5	
		Total..	19	16
Second Half Year				
75	Civil Eng. 2	Theory of Surveying	2	
68	Chemistry 4	General Inorganic Chemistry	3	
71	Chemistry 62	Qualitative Analysis	4	13
89	Mathematics 64	Calculus	5	
107	Phys. Educ. A	Gymnasium		2
108	Physics 4	Light, Sound, Electricity & Magnetism	5	
		Total..	19	15

SUMMER WORK: Civil Eng. 15s. Five weeks of surveying practice.

MINING ENGINEERING

General Statement

The instruction in the School of Mines during the first and second years includes fundamental training in mathematics, physics, mechanics, chemistry, mineralogy, and geology as outlined in the program of studies on page 25. Laboratory instruction in chemistry, assaying, drafting, mineralogy and geology extends through three years.

In the engineering, mining, and metallurgical laboratories the student is given opportunity for experimental study of these subjects, supplementing and illustrating the instruction given in the class room. These laboratories are also equipped to train the student in the making of scientific tests of engineering materials, and working tests of machines and processes of ore treatment, thus preparing him, as far as it is possible in the school, for work that he will be called upon to do as an engineer.

Practical instruction in summer classes in the field is made an important feature of the curriculum. Details of the summer courses in mining, metallurgy, field geology and surveying will be found on pages 30 and 31.

While much time is given to practical training in the laboratories, in the field, and at the mines and metallurgical establishments, care is taken to subordinate this instruction to a high standard of accomplishment in the regular classroom work.

The courses are severe, and should be undertaken only by those who are well prepared physically, mentally, and by previous training to devote themselves earnestly to the work required of them.

Advanced Students and Graduates can choose their subjects and plan of work much more freely than undergraduates.

Suggestions as to graduate work will be found on page 101.

Location—Many coal, iron, and other mines, together with quarries and metallurgical works, are easily accessible from New York in from one to four hours by rail. Among these are magnetic iron mines in New York, New Jersey, and Pennsylvania; stone quarries in the same States, and in Connecticut; anthracite and bituminous coal mines, and natural gas and oil wells in Pennsylvania, and zinc mines in New Jersey. New York and the adjacent States produce each year about half the pig-iron and coal, and over fifty per cent. of the total value of the mineral product of the whole country. There are within easy reach of New York City iron blast furnaces and some of the most skilfully designed and managed steel works, rolling mills, steel and iron foundries, copper smelting and refining works, lead-refining works, zinc works, and electrolytic establishments in the world. New York City, moreover, is the headquarters of many corporations operating mines and metallurgical works in this and other countries. Within a

radius of one hundred miles may be studied many phases of the best practice in mining and metallurgy in the country. By going a little farther one may reach the bituminous coal fields and the natural gas, oil and salt regions in one direction, and the pyrite deposits, and granite and marble quarries of New York and New England in the other; while the excursions of the summer class in mining extend as far as the copper, iron, zinc, lead, silver, and gold regions of Michigan, Missouri, Montana, Colorado, California, Arizona and Utah (see page 28).

Building—The six-story School of Mines building, given by Mr. Adolph Lewisohn, is 145 feet long by 57 feet in width. The basement and sub-basement contain the ore-dressing laboratories. On the main floor are the mining and metallurgical museums and lecture rooms. On the second floor are the offices of the department of mining, the mining and metallurgical department libraries, a drafting-room for the design work of the fourth year, and one of the metallurgical laboratories. On the third floor are the offices of the department of metallurgy, the furnace rooms, the chemical laboratory, metallographic laboratory, and the research laboratories of the same department.

Equipment

Lecture Illustrations—The lectures on mining are illustrated by sets of books aggregating over 300 volumes, and containing 85,000 selected blue prints, each student having the use of books of prints for home study and for reference during the lectures. These illustrations are supplemented by lantern slides or wall diagrams.

Mining Library—The University library contains complete sets of the transactions of all mining, metallurgical, and engineering societies, and of the more important periodical publications on these subjects. There is also a large collection of books on mining, and all new publications of value are added as they appear. In addition, a small departmental library has been created, which is accessible to students at all times.

Mining Museum—The subject of mining is illustrated by collections, as follows: Maps of coal and metal mines of this and other countries. Working drawings, diagrams, and photographs of mine plant, and of mining and dressing machinery. Models of mines and parts of mines, and of mine plant. Mining tools: picks, shovels, hammers, drills, blasting apparatus, lamps, safety-lamps, anemometers and machine drills. Ores and dressing products from typical works in this and other countries. Surveying instruments: geological compasses and clinometers, attraction compasses, dipping needles, hanging compasses and arcs, transits, lamp signals, rods, and apparatus for plumbing and measuring shafts.

Among the more notable exhibits is a large relief model of one of the mines of the Cleveland-Cliffs Iron Mining Co. of Michigan, a similar

model of a typical gold mine in Colorado, and a set of three glass models and two relief models of the Copper Queen Mine in Arizona, a model of the mine workings in the Mahanoy and Shenandoah anthracite coal basins Pennsylvania, a glass model of the mine workings on the Calumet Conglomerate of Houghton County, Michigan, a model of a standard oil-well drilling rig, and a model of the St. Joseph Lead Co.'s dressing works at Bonne Terre, Missouri. There is also a collection of working drawings of mine plant, and a large collection of underground photographs, taken by magnesium light.

Mining Laboratories—These laboratories, occupying seven rooms, serve to supplement the study of ore concentration and milling made by the student as a part of his summer work, and afford him facilities for such study that cannot well be given at the works. They include the following:

The Laboratory for Mechanical Assays contains appliances for quantitative work in hand picking, jigging and vanning small samples of ore, and for panning gold-bearing gravel. For small scale working tests there are a number of specially designed laboratory classifiers, jigs and slime tables.

The Crushing and Sampling Laboratory contains machinery for crushing and sampling large and small lots of ore, including gyratory and jaw crushers, rolls, a sample grinder, ball and pebble mills for fine crushing, gyratory screens, automatic samplers, and laboratory crushers, together with sieves, riffle samplers, etc.

The Laboratory for Working Tests contains a small vanning jig, an air jig, a buddle, a keeve, magnetic and electrostatic separators, and other similar apparatus for working a ton or more of ore at a time.

The Laboratory of Ore Dressing Machinery contains full-sized machines of standard types, each arranged so that the products, heads, middlings and tailings are returned at once to the same machine for re-treatment. With a small quantity of ore each machine can thus be operated as long as may be necessary, and the student is afforded an opportunity to become familiar with the adjustments of the machine and the tests of proper and successful working. The apparatus now installed includes three Harz jigs of two, three and five compartments, a Richards' pulsator jig and two pulsator classifiers, two round tables, concave and convex, a Johnston vanner, a Wilfley table, and a Stein-Bilharz belt table. On the floor below are full-sized classifiers, dewatering cones, automatic feeders, and centrifugal pumps for supplying these machines with water and ore for continuous work.

Mining Laboratory Instruction

The work required is designed (1) to illustrate the physical laws and practical conditions affecting the mechanical concentration, separa-

tion, and purification of minerals; (2) to instruct the students in the details of quantitative working tests on both small and large scale; (3) to train them in the adjustment and operation of the standard types of concentrating machines, and in testing the efficiency of such machinery in actual operation, and (4) to give opportunity for original research.

The work includes the reduction of a ton or more of ore to laboratory samples, and tests on portions of this ore by handpicking, hand jigging, and mechanical treatment on laboratory jigs, classifiers, and slime tables, to determine the proper method of mill treatment. These tests are controlled by crushing and vanning samples of the products, and reports of the results obtained are made in a systematic manner.

The large concentrators are arranged to be run continuously, for as many hours as may be necessary, using the same ore and the same water again and again. This is accomplished by running the products of the several machines through dewatering cones, from which the mixed material is transferred to the hoppers of automatic feeders. Variable speed pulleys permit any desired adjustment of the driving mechanisms. The water supply is drawn from a constant level tank fed by a centrifugal pump, and is regulated by dial cocks. Other adjustments are equally under control and can be varied at will.

With each of these machines the student makes a series of experiments designed to bring out the physical laws governing successful working, to afford instruction in the practical details of operating the machines, and to give opportunity for engineering tests of capacity and efficiency under different conditions of treatment. These include the adjustment and regulation of the ore supply, of the feed and wash water, of speed, stroke, and other working conditions to the treatment of different ores and different grades of sand and pulp. In this work the student is taught to recognize the symptoms of irregular working, to diagnose the trouble with the aid of laboratory tests, and to apply the proper remedy. Incidentally he makes tests of capacity and efficiency, taking frequent samples of the ore feed, and of the different products for quantitative examination, and weighs and measures the ore and water supply and products obtained.

Experiments of this kind for purposes of instruction cannot well be made at concentration works in the field. There the machines must work regularly and without interruption, and any interference with the ore feed, water supply, or other adjustments may occasion loss of valuable mineral.

Research Work—The laboratories have facilities for original investigation in the physical laws controlling the mechanical treatment of minerals.

Original researches have recently been undertaken by graduate students in:

Investigation of magnetic fields with reference to ore-concentration; the effect of variations in the speed of crushing machinery on the production of undersized material; the amalgamation of gold ores; an investigation of the laws of jigging.

Summer Courses

Summer Courses in Surveying—About five weeks' work in surveying is required of each class between the first and second years, and eight weeks between the second and third years. See page 44.

Summer Course in Mine Surveying—One week is spent at a mine in underground surveying. In 1909 and again in 1910 this work was done at the Orchard Mine, Wharton, N. J.

Summer Course in Practical Mining—Six weeks are spent in detailed study of the plant and methods of working at some mine or mines and in excursions to other mines and mining regions. The course includes shaft-sinking, drifting, stoping, timbering, underground haulage, hoisting, mine drainage, ventilation, surface plant, mine buildings, repair shops, houses, etc., water supply, organization, administration, and underground surveying. Arrangements are made at numerous mines, by which the students, singly or in small groups, may do the work described above according to a definite plan and under the general direction of the department.

These summer courses have been in operation since 1877, and have proved themselves an indispensable adjunct to the regular curriculum. They bear the same relation to the study of mining as laboratory work to the study of chemistry or physics, or clinical instruction and hospital practice to the study of medicine.

In 1908, a division of the class, in charge of an instructor, studied at the lead mines of the Federal Lead Co., Flat River, Mo., and the zinc mines of the Joplin district, Mo. The larger part of the class was sent out in separate squads to copper, iron, gold and silver mines in the West, at which arrangements were previously made and the necessary privileges secured. Among these mines were the Wolverine, Michigan; Golden Reward, Mogul and Homestake, South Dakota; Silver Bow and others of Butte, Montana; the properties of the Tennessee Copper Co., and a number of mines in Bisbee, Tombstone, Cananea, Cripple Creek and Leadville. Several members of the class obtained underground work in the Center Star and War Eagle mines, British Columbia, in Butte and elsewhere. The class numbered 40 men.

In 1909 the entire class of 39 students was again distributed in small squads at gold, silver, copper, zinc, lead, coal and iron mines, in Colorado, Utah, Arizona, Idaho, Montana, Michigan, Missouri, Tennessee and Pennsylvania. The time occupied was from 7 to 10 weeks.

In 1910, the class, numbering 43 men, was scattered through 16 States and for the required work visited over 60 mines.

In 1905 and 1906 the non-ferrous summer class in metallurgy visited copper, lead, gold, silver and zinc works in the vicinity of New York City. The work in iron and steel was performed at several iron and steel works in the vicinity of Pittsburg in 1905. In 1907 students in metallurgy visited more than twenty iron and steel plants near Pittsburg. In 1908 and 1909 and 1910 this work was done chiefly in the several districts visited by the squads of mining students.

This work was supplemented in 1910 by organized trips in June and in November to metallurgical plants in the vicinity of New York.

Summer Courses in Geology—One week is devoted to practical field geology. The class is instructed in methods of field observation, locating outcrops, measuring dip and strike, keeping notes, etc., afterward constructing maps and geological sections from the observations noted; all under the supervision of the Professor of Geology.

Other Departments

Information as to instruction and the equipment available for students of Mining and Metallurgy in other departments of the University is to be found in this pamphlet as follows:

Chemistry and Assaying, 69; Civil Engineering and Surveying, 75; Electrical Engineering, 82; Geology, 86; Mathematics, 88; Mechanical Engineering, 89; Mineralogy, 102; Physics and Mechanics, 108; Metallurgy, 98.

ENGINEER OF MINES

The four-year course leading to the degree of Engineer of Mines is intended primarily to train men to undertake the development of mineral properties, the design and construction of mine plants, and to manage mines. It is necessarily a broad one, comprising a wide range of studies in pure and applied science, and for this reason is frequently taken by students desiring a general scientific training.

The subjects most emphasized in this course are mining, metallurgy, geology, and engineering. Metallurgy requires knowledge of inorganic and applied chemistry, qualitative and quantitative analysis, and assaying. Geology must carry with it preliminary training in crystallography, mineralogy, and petrography.

Engineering in all its branches needs a fundamental knowledge of mathematics, physics, mechanics, and thermodynamics. The proper design and construction of mining plants involves the study of certain branches of civil engineering, and the many and increasing applications of machinery to mining make it necessary to give much time to the theory and practice of mechanical and electrical engineering.

FIRST YEAR

See page 25

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
75	Civil Eng. 23	Theory of Railroad Surveying	2	3
81	Drafting 7	Structural Drafting		3
86	Geology 5	General Geology	3	
108	Physics 5	Electricity	5	
89	Mathematics 65	Calculus	5	
102	Mineralogy 1	Mineralogy	3	6
107	Phys. Educ. B	Gymnasium		2
		Total..	15	14
Second Half Year				
71	Chemistry 66	Quantitative Analysis	3	12
73	Chemistry 82	Industrial Chemistry	3	
82	Elect. Eng. 2	Elements of the Dynamo	2	
86	Geology 6	General Geology	3	
108	Mechanics 102	Analytical Mechanics	5	
102	Mineralogy 2	Mineralogy	3	3
107	Phys. Educ. B	Gymnasium		2
		Total..	16	14

SUMMER WORK: Civil Eng. 27s and 28s, Practical Surveying (eight weeks).

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
76	Civil Eng. 53	Resistance of Materials	5	3
76	Civil Eng 53	Resistance of Materials (Testing Lab.)		3
72	Chemistry 69	Assaying	2	9
87	Geology 105	Economic Geology	3	
89	Mech. Eng. 13	Steam Power Machinery	3	
90	Mech. Eng. 17	Technical Thermodynamics	2	
103	Mining 51	Excavation and Tunneling	3	
		Total..	18	15
		Second Half Year		
76	Civil Eng. 54	Resistance of Materials—problem work		3
78	Civil Eng. 64	Graphic Statics	1	3
82	Elect. Eng. 72	Direct Current Laboratory		3
82	Elect. Eng. 4	Electric Distribution	2	
86	Geology 4	Petrography (6 hrs. for 2 months)		3
87	Geology 106	Economic Geology	3	
89	Mech. Eng. 14	Steam Power Machinery	3	
97	Mech. Eng. 76	Experimental Mechanical Engineering	1	3
102	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 mos.)		3
103	Mining 52	Boring & Shaft Sinking	2	
103	Mining 54	Methods of Mining	3	
		Total..	15	18

SUMMER WORK: Field work, Mining, Metallurgy, and Geology (8 to 10 weeks).

FOURTH YEAR

		First Half Year		
83	Elect. Eng. 75	Alternating Current Laboratory	1	3
88	Geology 201	Petrography (elective)		
98	Metallurgy 101, 111	Introduction to Metallurgy and Metallurgy of Copper	3	
99	Metallurgy 131, 141	Electro-Metallurgy and Iron and Steel	2	
104	Mining 71	Mine Plant	3	
104	Mining 73	Mine Constructions	1	
104	Mining 75	Design of Mine Plant		12
105	Mining 81	Ore Dressing	4	
105	Mining 91	Mine Administration and Accounts	2	
		Total..	16	15
		Second Half Year		
78	Civil Eng. 76	Hydraulics	2	
87	Geology 16	Paleontology (elective)		
88	Geology 110	Geological Surveys	2	
97	Mech. Eng. 74	Gas Power Machinery	2	
101	Metallurgy 72	Metallurgical Laboratory (10 afts)		2
99	Metallurgy 122	Metallurgy of Gold, Silver, etc.	3	
104	Mining 56	Mine Engineering	3	
104	Mining 72	Mine Plant	3	
104	Mining 78	Thesis		12
105	Mining 80	Mill Constructions	1	
105	Mining 82	Ore Dressing (Lab.)—(afts. of 3 weeks)		3
106	Mining 94	Mining Law	2	
		Total..	18	17

METALLURGICAL ENGINEERING

General Statement

The primary aim of the four-year course leading to the degree of Metallurgical Engineer is to train students to take administrative or laboratory positions in metallurgical works. Great stress is laid on the original planning and executing of work, under constant criticism and discussion from the teachers.

The undergraduate instruction consists of (1) class-room work, lectures, conferences, study of text-books; (2) general laboratory work in metallurgy; (3) training in planning and executing original research; (4) summer courses and other visits to industrial metallurgical works.

Much importance is attached to a thorough training in the fundamental subjects, mathematics, chemistry, physics, geology, mineralogy, and engineering, and to the higher branches of engineering, chemistry and important courses in mining engineering, with a view to their applications to metallurgical and like manufacture.

The instruction in metallurgy is based on the most advanced practice in science of to-day and covers the ground from the introductory courses in metallurgy to the special advanced courses in the various branches of the subject.

To graduate and other *advanced students* and properly qualified *practitioners* the department's laboratories are open under generous restrictions.

Location and Equipment

Location. For the advantages of New York and the adjacent states see page 26.

Metallurgical Establishments Accessible. Some of the most instructive and advanced iron, steel, copper, lead, zinc, and electrolytic works in the world are accessible to students for the study of many phases of the best metallurgical practice. See also page —. The summer classes visit in different years metallurgical establishments in all parts of the country, including the extreme West and South.

Building. The department occupies about half the new School of Mines Building. See page 27.

Collections. There are large and growing collections of lecture diagrams; of models and working drawings of metallurgical furnaces and machinery; of apparatus for lecture demonstration and illustration of metallurgical principles and processes; and a very large collection of metallurgical specimens and suites, with descriptive and explanatory notes. The metal-working shop has power-driven machines for cutting specimens, etc. Most of the furnaces are gas-fired, and those furnaces which are intended for precise work are heated by electric resistance.

Metallurgical Laboratories. Of these there are three. They serve four chief purposes: (1) to give skill in the use of the instruments of precision of the art; (2) to teach the underlying principles of metallurgy and give familiarity with the conditions, especially as to high temperature, under which metallurgical operations must be carried on, and the use of the principal types of furnaces and other metallurgical apparatus, or in short "Analytical metallurgy"; (3) to give some acquaintance with certain industrial metallurgical processes, or what may be called "Applied metallurgy"; and (4) to give advanced students and qualified practitioners the means of making metallurgical and metallographic researches.

The Instruments of Precision. The students acquire skill with the thermo-electric pyrometer, some industrial and some autographic, with the Wanner optical and the Fery radiation pyrometer, besides which they have the opportunity of using the Mesuré and Noel (Ducretet) and the Le Chatelier optical and the Calorimetric one of Siemens. There are ammeters and voltmeters for controlling the electric furnaces; sclerometers for measuring hardness; Fremont and Brinell impact testing machines; a tensile testing machine; a Berthelot calorimeter for testing fuels; and many other instruments.

Non-Ferrous and Electro-Metallurgical Laboratory. A. For wet and dry metallurgy, the extraction, refining, and alloying of the non-ferrous metals, there are ore-roasting furnaces; gas-fired crucible furnaces; assay muffle furnaces; a high temperature forge; cyanide plants; a filter press; amalgamating pans; a chlorinating barrel; ball mills; two desilverization kettles; and pyrometers. B. For electro-metallurgy, the electrical recovery, deposition, refining, and alloying of metals, there are storage batteries; electrolytic refining vats; and electric furnaces of the Moissan arc, Borchers arc and resistance types.

The Iron and Steel Laboratory. Here there are electric and double muffle gas furnaces especially designed for this laboratory, in which many full-sized tensile test bars may simultaneously be heated to any temperature up to 1300° C., with uniformity and precision; gas and direct-fired crucible furnaces; gas forges; many special furnaces; and small power-driven rolls for studying the influence of the conditions of rolling on the properties of metals.

The Metallographic Laboratories, for the microscopic and pyrometric study of metals, mattes, slags, etc., in which every student in metallurgical engineering has to become skillful, has microscopes of the Leitz, Le Chatelier, Swift, Beck, and other types; equipment for illumination and photography; electric resistance furnaces of different types; portable gas furnaces; and pyrometers.

An Analytical Laboratory in which the students apply to their own metallurgical researches the methods of chemical analysis already learned in the Department of Chemistry (p. 68).

Supplies. There is a large stock of ores, irons, steels, alloys, refractory materials, fluxes, etc., which may be used for investigations.

The Metallurgical Library, containing about fifteen hundred volumes of metallurgical treatises, text-books, periodicals, etc., is open to all students, and to others properly introduced. Books may be borrowed under suitable restriction.

Metallurgical Laboratory Instruction

In order to become familiar with a wide range of the conditions and principles of metallurgy, the student makes many experiments, each illustrating, testing, or aiming to discover some one or more metallurgical principles or reactions, or the conditions which permit a given reaction to occur. He must, in general, after each experiment enunciate briefly in writing the law to which his results point, or indicate how far those results severally and collectively support or oppose a given proposition.

These experiments relate chiefly to such subjects as the influence of thermal treatment on the properties and microstructure of metals and alloys, especially iron and steel; the determination of melting points and other temperatures; the relation between the composition of slags and their fusibility; the influence of fluxes; the behavior of refractory materials at high temperatures, either alone or in contact with different slags; the temperature limits and the reactions of roasting operations; the influence of various bodies on the reactions which take place in roasting, in the cyanide process, in the chlorination process, and in pan amalgamation; the interaction of carbon and molten oxides, sulphides, silicates, etc., etc.

Summer Courses

Summer Courses in Metallurgy—No. 62s for mining engineers consisting of visits to non-ferrous metallurgical plants for a period of one week.

For metallurgical engineers the summer course lasts six weeks and includes No. 64s, visits to iron and steel metallurgical plants, and 66s, visits to plants for other metals. On these trips, which cover the practice in both the east and the west, the students are instructed in the actual metallurgical operations as carried on in the field. A prominent part of these courses consists of work such as making written descriptions of the processes, and sketches of the furnaces and other apparatus, with dimensions, usually from the student's own estimate; explaining the principles on which the processes rest, the reasons for the special shapes and sizes of the apparatus, the chief technical difficulties, how they are overcome, and by what tests the processes are controlled; giving the number of men, and, as far as practicable,

the consumption of fuel and other materials, the thoroughness of recovery of the metal sought, etc. From an imaginary set of prices and wages the students have to calculate the cost and profit of certain operations.

Summer Courses in Surveying—About thirteen weeks' work in surveying is required of the class between the first and second years. See page 42.

Summer Courses in Geology—After the third year at least one week is devoted to practical field geology. For details see page 86.

Metallurgical Excursions—At stated times excursions, open only to students in Metallurgical Engineering, are made to the neighboring foundries, machine shops, mines, and other points of interest. The students attend these excursions in squads of such size that proper individual instruction can be given to each member of the squad.

Other Departments

Information as to instruction and the equipment available for students of Mining and Metallurgy in other departments of the University is to be found in this pamphlet as follows:

Chemistry and Assaying, page 68; Civil Engineering and Surveying, page 75; Electrical Engineering, page 82; Geology, page 86; Mathematics, page 88; Mechanical Engineering, page 89; Mineralogy, page 102; Mining, page 103; Physics and Mechanics, page 108.

COURSES LEADING TO THE DEGREE OF METALLURGICAL ENGINEER

This course, which covers four years, is intended for those who expect to follow metallurgical work and become trained metallurgists in any of the branches of the profession. For the first two years much attention is paid to a thorough training in fundamental subjects, especially in mathematics, chemistry, physics, geology, mineralogy, and preliminary courses in engineering. In the third year instruction in metallurgy begins both by lectures and in the laboratories, while courses in engineering, especially mechanical engineering, chemistry, and geology, are also provided for. The fourth year is devoted largely to advanced courses in metallurgy, and great stress is laid on giving, by laboratory work, familiarity with difficult high temperature conditions of metallurgy, skill in microscopy and pyrometry and training in execution and in the interpretation of the results developed. At the same time attention is devoted to the higher branches of engineering and chemistry and to important courses in mining engineering which are considered necessary.

In the summer schools, carefully arranged courses in general surveying, in railroad work, geological field work, and visits to metallurgical works are provided for. In the six weeks' summer courses at metallurgical works, the students are required to carefully study processes, make dimension sketches of furnaces and mills, and by observation and instruction are given a thorough understanding of metallurgical operations as conducted at the present time.

FIRST YEAR

See page 33

SECOND YEAR

		First Half Year	Hours per week	
See Page			Class	Lab'y
75	Civil Eng. 23	Theory of Railroad Surveying	2	3
108	Physics 5	Electricity	5	
89	Mathematics 65	Calculus	5	
103	Mineralogy 7	Mineralogy	3	3
86	Geology 5	General Geology	3	
108	Physics 43	Physical Laboratory		6
81	Drafting 7	Structural Drafting		3
107	Phys. Educ. B.	Gymnasium		2
		Total..	18	17
		Second Half Year		
71	Chemistry 66	Quantitative Analysis	3	12
73	Chemistry 82	Industrial Chemistry	3	
82	Elect. Eng. 2	Elements of the Dynamo	2	
86	Geology 6	General Geology	3	
103	Mineralogy 8	Mineralogy	3	3
108	Mechanics 102	Analytical Mechanics	5	
107	Phys. Educ. B.	Gymnasium		2
		Total..	19	17

SUMMER COURSES: Surveying Practice 5 weeks (Civil Eng. 27S).
Surveying Practice 3 weeks (Civil Eng. 28S).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
76	Civil Eng. 53	Resistance of Materials	5	6
73	Chemistry 69	Assaying	2	9
87	Geology 105	Economic Geology	3	
89	Mech. Eng. 13	Steam Power Machinery	3	
98	Metallurgy 101	Introduction to Metallurgy	1	
98	Metallurgy 111	Metallurgy of Copper	2	
		Total..	16	15
		Second Half Year		
78	Civil Eng. 64	Graphic Statics	1	3
78	Civil Eng. 76	Hydraulics	2	3
82	Elect. Eng. 72	Direct Current Laboratory	1	3
86	Elect. Eng. 104	Electric Distribution	2	
86	Geology 4	Petrography		3
87	Geology 106	Economic Geology	3	
102	Mineralogy 6	Optical Mineralogy		3
89	Mech. Eng. 14	Steam Power Machinery	3	
99	Metallurgy 122	Metallurgy of Lead, etc.	3	
103	Mining 54	Methods of Mining	3	
		Total..	18	15

SUMMER COURSES: Non-ferrous Works Visits 3 weeks (Met. 66S). Iron and Steel Works Visits 3 weeks (Met. 64S). Geology Field Work 1 week (Geol 112S).

FOURTH YEAR

		First Half Year		
69	Chemistry 121	Physical Chemistry	3	
83	Elect Eng. 75	Alternating Current Laboratory	1	3
90	Mech. Eng. 17	Technical Thermodynamics	2	
99	Metallurgy 131	Metallurgy of Iron and Steel	1	
100	Metallurgy 141	Electrometallurgy	1	
100	Metallurgy 151	Constitution of Alloys	2	
101	Metallurgy 171	Metallurgical Laboratory		9
101	Metallurgy 175	Metallurgical Investigation	1	
101	Metallurgy 177	Metallurgical Plant Construction		3
104	Mining 73	Mine Constructions	1	
105	Mining 81	Ore Dressing	4	
105	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
69	Chemistry 122	Physical Chemistry	3	
96	Mech. Eng. 72	Gas Power Machinery	2	3
97	Mech. Eng. 76	Experimental Mech. Engineering	1	3
98	Metallurgy 118	Advanced Metallurgy of Copper	1	
99	Metallurgy 128	Advanced Metallurgy of Lead, etc.	1	
100	Metallurgy 138	Advanced Metallurgy of Iron and Steel	1	
100	Metallurgy 148	Advanced Electrometallurgy	1	
101	Metallurgy 172	Metallurgical Laboratory		6
105	Mining 80	Mill Construction	1	
105	Mining 82	Ore Dressing		3
106	Mining 94	Mining Law	2	
		Total..	15	15

CIVIL ENGINEERING

General Statement

The four-year course leading to the degree of Civil Engineer is designed to afford a thorough analytical training in construction and management. The course contains numerous and extended practical exercises in those matters which pertain to the profession of the civil engineer in relation to all classes of structures and public works and in connection with the various developments and applications of power by the use of steam, electric, water, and air motors. This course is also designed to be an educational preparation for those duties or functions of an executive character whose discharge in connection with the management of public or other works requires, or is rendered more efficient through, a thorough knowledge of civil engineering. The breadth and nature of this educational training adapts it no less efficiently to the purposes of those who intend to follow callings not of an engineering character but which may be related more or less to manufacturing, to structural matters, or to the development and application of power. The theoretical portion of the instruction is based largely upon the courses given in the departments of Mathematics, Mechanics, and Physics, and the results obtained are applied to practical engineering work. Special stress is laid upon the design by the student of the various structures and machines which the civil engineer is called upon to construct or operate in the practice of his profession. The instruction is given by lectures, demonstrations by the student, and frequent conferences, co-ordinate with which the work of design is continuously carried on. It covers comprehensively the subjects of surveying, road and railroad engineering, water supplies of cities and towns, irrigation, sanitary engineering, including sewage disposal, both graphic and analytic treatment of all metallic structures, foundations, retaining and reservoir walls, high masonry dams, sewer systems, hydraulic engineering, rivers and harbors, pumping engines, hydraulic, steam and electric motors.

Ample facilities are afforded for post-graduate students in civil engineering, and special students are admitted to various engineering courses of the department upon evidence of proper qualifications.

Equipment

The school possesses an unusually full equipment of engineers' and solar transits, levels, plane tables, compasses, and all accessories, as well as smaller instruments. Current meters, hook gauges, and floats of various types are also used in making observations on the flow in, and

discharge of, rivers and canals. A complete set of sections of iron and steel shapes, models and photographs of engineering works, together with working plans of the latter, are in the department for the use of students. The hydraulic laboratory affords opportunity for the practical operations of measuring the discharge through weirs and other orifices, the flow through open channels and closed pipes, frictional and other resistances in pipes and open channels, as well as for meter gaugings, and for general hydraulic investigations. The testing work in the mechanical laboratory includes the complete tests of various structural materials in tension, compression, bending, and torsion, including the observation and digesting of all corresponding data.

A cement-testing laboratory is fully equipped with testing machines, briquette molds, tanks, and other apparatus requisite for all classes of investigations in the nature and physical properties of cements and cement mortars.

A complete laboratory for the testing of road materials has been established and is constantly in use for investigations connected with materials suitable for road building. The facilities offered by the laboratory are full and sufficient to make all tests required to determine resistance to abrasion, classification of sand, gravel and broken stone and the cementing power of all qualities of road materials. The laboratory is at the service of students and is used by them, both for the ordinary prosecution of studies to which the determination of results is related and for the purposes of thesis work, and other similar investigations.

The Materials Testing Laboratory is located at the north end of the main floor of the Engineering Building. It is fully equipped with modern appliances for the conduct of tests upon all structural materials. There are seven testing machines varying in capacity from 600 lbs. to 400,000 lbs., representing all American types, including a 150,000-lb. Emery hydraulic power machine, which is a standard of accuracy, and the refinement of mechanical construction. These machines are suited to make tension, compression, transverse and torsion tests upon metals, also to make all desired tests upon building materials, such as timber, stone, brick, concrete blocks or concrete-steel beams, columns, partition blocks, and all built up materials.

The laboratory is also liberally supplied with a large assortment of extensometers, deflectometers, micrometers, gauges, and similar instruments of precision for measurement of test pieces.

Other apparatus, such as delicate scales of different sizes for use in absorption and freezing tests on building materials, also pyrometers and furnaces for the conduct of fire tests upon all kinds of fire-resisting materials are available.

General Statement of the Summer Courses in Surveying and Geodesy at Camp Columbia, Morris, Conn.

The instruction in Surveying given by the Department of Civil Engineering consists of lectures, recitations and problem work, supplemented by instrumental practice in field work, and office work in computation and mapping. The general lectures and recitations are given at the University. The field practice is given during the three summer vacations of the regular four-year course. The subject of Geodesy is given by the Department of Astronomy, and the practical work connected therewith is done under the supervision of that department by students in Civil Engineering during a portion of five weeks of the summer vacation between the third and fourth years. The theory of Plane Surveying, including Railroad Surveying, is given by the Department of Civil Engineering. The field practice is conducted under the direction of the Department at Camp Columbia, a point in the country near Litchfield, Conn., where ample facilities are provided for all requisite operations, and where the topography and climate are admirably adapted to the practical work of surveying. Five weeks' continuous attendance is required of all students in the Schools of Mines, Engineering and Chemistry during the summer between the first and second years. (See C. E. 15, page 75.) Five weeks' additional attendance is required of all students in Civil Engineering (see C. E. 25, page 75), and eight weeks of all students in Metallurgy, and eight weeks of all students in Mining (see C. E. 27 and 28, page 76) during the summer between the second and third years. Nine weeks' continuous attendance is required of all students in Civil Engineering during the summer between the third and fourth years (see C. E. 26, Astronomy 107 and C. E. 71, pages 76, 68, 78). During the summer of 1911 the Summer Courses in Surveying and Geodesy will be in session about fifteen weeks.

No student taking these courses will be excused from any part of any course on account of work done elsewhere, unless that work has been done under the immediate direction of an instructor of an institution which grants degrees in Mining or Civil Engineering. In no case will credit be given except upon the evidence of field-notes, maps, and reports presented to the Professor in charge of the courses.

Two examinations will be held at Camp Columbia for new students, special students and students who fail to receive a mark of 5.0 (this is not a passing mark in C. E. 2, but entitles the student to take Course C. E. 15) or more in C. E. 2, and this examination must be taken by these men before they begin field work. The first examination will be held July 7 for students who desire to enter with Div. G, and the second one August 11, 1911, for students who desire to enter with Div. I.

The University provides houses or tents having elevated floors, fur-

SCENES AT CAMP COLUMBIA

nished with cots and drafting tables. There are also provided a dining hall and bath house. Arrangements may be made for laundry work to be done in the neighborhood. A supply of drafting materials (not instruments) is kept on sale. Especial attention is given to the wholesome and substantial character of the table.

The cost of board is $6.75 per week and is charged against the individual deposits. The account against each student is reckoned from the day announced for his division to assemble. No allowances or reductions are made for absences of less than one week, and then only in the event of notice having been given and excuse granted by the officer in charge at least one day in advance of the beginning of such absence.

Each student intending to take work in these courses must register with the Registrar of the University not later than May 10. Subsequent changes in plans must be reported at once.

Every student must be present on the day appointed for his division to assemble, unless other arrangements have been made with the officer in charge. Failure to comply with this regulation may be sufficient cause to refuse the applicant's admission to the courses.

Deposits for Camp Expenses

Every student before starting for Camp, and at the same time the fees for the summer session in surveying are paid, shall make a deposit at the Bursar's office at Columbia University to meet Camp expenses, viz., board, laundry, charges for drawing material, notebooks, etc.; also to cover any damage to, breakage, or loss of instruments or Camp equipment, and transportation of self and baggage from the station to and from the Camp. The Bursar's receipt for said deposit shall be presented to the professor in charge of the summer session upon the arrival of the student in Camp.

The amounts of the deposit varies with the course or the number of courses taken and is as specified below. Students intending to take two or more courses shall deposit an amount equal to the sum total of the deposits herein specified for the respective courses. The balance of the deposit which shall remain to the credit of the student after his withdrawal from the session will be returned to him during the following October upon his application to the Bursar of Columbia University. In case the total charges exceed the deposit the student will be subject to an additional assessment.

For schedule of fees and deposits, see page 18.

Schedule of Attendance

In 1911 the School Session opens June 3 and closes September 16.

Div. A—June 3 to July 8, 5 weeks—Course **25**.
Open for all 2d, 3d, 4th year students in Civil Engineering who have completed Course **15**.

Div. B—June 3 to July 8, 5 weeks—Course **27**.
Open for all 2d, 3d, 4th year students in Mining Engineering and Met. Engineering who have completed Course **15**.

Div. C—June 3 to July 8, 5 weeks—Course **15**.
Open for all 2d, 3d and 4th year students in the Schools of Mines, Engineering, and Chemistry who have not finished Course **15**.

Div. D—June 3 to July 8, 5 weeks—Course **15**.
Open for 20 or 25 men of all 1st year students as assigned on basis of scholarship.

Div. E—July 8 to August 12, 5 weeks—Course 25.
Open for 2d, 3d, 4th year students in Civil Engineering who reported with Div. C or Div. D for Course **15**.

Div. F—July 8 to August 12, 5 weeks—Course **27**.
Open for 2d, 3d, 4th year students in Mining and Metallurgy who reported with Div. C or Div. D for Course **15**.

Div. G—July 8 to August 12, 5 weeks—Course **15**.
Open for 1st year students as assigned from those not assigned to Div. D and of those who do not register for the summer session in New York. (Probably 75 men.)

Div. H—July 15 to August 19, 5 weeks—Course **26** C. E. and Course **107** Astronomy.
For 3d and 4th year students in Civil Engineering who have finished Course **15** and Course **25**.

Div. I—August 12 to September 16, 5 weeks—Course **15**.
For 1st year students as assigned from those not assigned to Div. D or Div. G. (Special dates may be arranged for those who attend Summer Session at Columbia University in New York.)

Div. J—August 19 to September 16, 4 weeks—Course **71**.
For 3d and 4th year students in Civil Engineering who have finished Course **15**, Course **25** and Course **51-52**.

Div. K—August 17 to September 16, 4½ weeks—Part of Course **25** or Course **27**.
For 2d, 3d, 4th year students in Mining, Metallurgy and Civil Engineering who reported with Div. C and who withdrew with permission on July 4 to attend Summer Session at Columbia University, in New York.

Div. L—*August 17 to September 16, 4½ weeks—Part of Course **15**.

For special students not heretofore registered at Columbia University but who have been in attendance at Summer Session at Columbia.

Div. M—August 26 to September 16, 3 weeks—Course **28**.

For 2d, 3d, 4th year students in Mining and Metallurgy who have finished Course **15**, Course **27** and Course **23**.

* Special students wishing to enter this course and who are not in attendance at Summer Session in New York should report August 12.

COURSE LEADING TO THE DEGREE OF CIVIL ENGINEER

FIRST YEAR

See page 33

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
68	Botany 7	Growth and Character of Timbers	1	3
81	Drafting 5	Graphics		3
108	Physics 5	Electricity	5	
89	Mathematics 65	Differential and Integral Calculus	5	
89	Mech. Eng. 13	Steam Power Machinery	3	
102	Mineralogy 5	Minerals of Building Stones	2	2
103	Mining 53	Excavation, Tunneling, Boring and Shaft-sinking	2	
107	Phys. Educ. B	Gymnasium		2
111	Shop Work 15	Forging and Foundry Practice		3
108	Physics 43	Physics Laboratory		3
		Total..	18	16
Second Half Year				
73	Chemistry 82	Industrial	3	
81	Drafting 6	Graphics		3
81	Drafting 8	Structural Drafting		6
82	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	*3
89	Mech. Eng. 14	Steam Power Machinery	3	
108	Mechanics 102	Analytical Mechanics	5	
99	Metallurgy 134	Iron and Steel	2	
107	Phys. Educ. B	Gymnasium		2
108	Physics 44	Physics Laboratory		3
111	Shop Work 16	Machine-work		3
		Total..	18	18

*Saturday P.M., 1 afternoon during April and May—equivalent 1 hour.
SUMMER WORK: Practical Surveying Civil Eng. 25S—5 weeks.

THIRD YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
68	Astronomy 105	Geodesy	3	
75	Civil Eng. 21	Roads, Streets and Pavements	1	
76	Civil Eng. 51	Railroad Surveying	2	3
76	Civil Eng. 53	Resistance of Materials	5	3
76	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
77	Civil Eng. 59	Sanitary Treatment, Water Supply and Sewage	2	
77	Civil Eng. 61	Theory of Trusses	2	3
90	Mech. Eng. 17	Technical Thermodynamics	2	
97	Mech. Eng. 77	Mechanical Laboratory	1	3
		Total..	18	15
Second Half Year				
68	Astronomy 106	Geodesy	1	3
76	Civil Eng. 52	Railroad Surveying	3	3
76	Civil Eng. 54	Resistance of Materials (Problems)		3
77	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
82	Elect. Eng. 72	Direct Current Laboratory	1	3
82	Elect. Eng. 4	Electric Distribution	2	
90	Mech. Eng. 18	Technical Thermodynamics	2	
97	Mech. Eng. 78	Kinematics	3	
		Total..	17	18

SUMMER WORK: { Hydrographic Surveying—Civil Eng. 26S; Geodetic " —Astronomy 107S } 5 weeks.
Railroad surveying practice—Civil Eng. 71S—4 weeks.

FOURTH YEAR

First Half Year				
78	Civil Eng. 75	Hydraulics	4	
78	Civil Eng. 85	Foundations	2	3
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
79	Civil Eng. 89	Railroad Engineering	3	3
85	Civil Eng. 98	Water Supply and Irrigation Eng.	2	
80	Civil Eng. 99	Thesis		3
93	Mech. Eng. 41	Machine Design	1	3
95	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	14	18
Second Half Year				
79	Civil Eng. 88	Bridges, Roofs and Buildings	2	3
79	Civil Eng. 90	Railroad Engineering	3	3
79	Civil Eng. 94	{ Design and Construction of Sewers; River and Harbor Improvement }	2	
97	Law 2	Business Law	2	
80	Civil Eng. 100	Thesis	3	6
83	Elect. Eng. 76	Alternating Current Laboratory	1	3
84	Elect. Eng. 112	Electric Railway	2	
93	Mech. Eng. 46	Hydraulic Power Machinery	3	
		Total..	18	15

COURSE IN SANITARY ENGINEERING

The course in Sanitary Engineering is a differentiation from the regular course in Civil Engineering and naturally leads, therefore, to the same degree. The first year is identical with the first year of other engineering courses, while the second year is almost identical with the regular second-year work of the course in Civil Engineering. The special extensions in sanitary work are developed in the third and fourth years. It will be found that these sanitary subjects are set forth so as to cover in a thorough and comprehensive way those special fields occupied by the sanitary engineer of the present day. They include the sanitary treatment of water supplies and sewage with special work extended both by lectures and laboratory work into biology and bacteriology, standard laboratory methods in the sanitary administration of public water supplies, drainage, heating and ventilation and the general principles of sanitary science, public health and hygiene. These sanitary specialties are of advanced character, covering the latest investigations in such special work as daily bacterial tests of potable water for public purposes, the extermination of mosquitoes and other disease-carrying insects, the improvement of public health conditions found in cities and towns, the drainage and sanitary treatment of lands and the sanitary administration of buildings and industrial establishments liable to create nuisances. A graduate, therefore, of this course is qualified to enter the advanced practice of sanitary engineering in all its special fields.

SECOND YEAR

First Half Year			Hours per week	
See Page	Name of Course	Description of Course	Lect.	Lab'y
68	Botany 7	Growth and Character of Timbers	1	3
71	Chemistry 65	Quantitative Analysis	2	6
81	Drafting 5	Graphics		4
108	Physics 5	Electricity	5	
89	Math. 65	Differential and Integral Calculus	5	
89	Mech. Eng. 13	Steam Power Machinery	3	
102	Mineralogy 5	Minerals of Building Stones	2	2
107	Phys. Educ. B	Gymnasium		2
		Total..	18	17
Second Half Year				
73	Chemistry 82	Industrial Chemistry	3	
81	Drafting 8	Structural Drafting		2
82	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	3*
108	Mechanics 102	Analytical Mechanics	5	
89	Mech. Eng. 14	Steam Power Machinery	3	
99	Metallurgy 134	Iron and Steel	2	
108	Physics 44	Physics Laboratory		6
111	Shop Work 16	Bench and Machine		3
74	Chemistry 92a	Microscopy		2*
107	Phys. Educ. B	Gymnasium		2
		Total..	18	15

* February and March—Microscopy ; April and May—Geology.
SUMMER WORK : Practical Surveying C.E. 25—5 weeks.

THIRD YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
75	Civil Eng. 21	Roads, Streets, and Pavements	1	
111	Zoology 7	Sanitary Biology }	2	6
68	Bacteriology 101	Sanitary Bacteriology }		
76	Civil Eng. 51	Railroad Surveying	2	3
76	Civil Eng. 53	Resistance of Materials	5	3
76	Civil Eng. 53	Resistance of Materials Testing		3
77	Civil Eng. 59	Sanitary Treatment of Water Supplies and of Sewage	2	
77	Civil Eng. 61	Theory of Trusses	2	3
71	Chemistry 41	Organic Chemistry	2	
		Total..	16	18
		Second Half Year		
76	Civil Eng. 52	Railroad Surveying	3	3
76	Civil Eng. 54	Resistance of Materials		3
77	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
70	Chemistry 42	Organic Chemistry	2	
82	Elect. Eng. 72	Direct Current Laboratory	1	3
82	Elect. Eng. 4	Electric Distribution	2	
97	Mech. Eng. 78	Kinematics	3	
		Total..	16	15

SUMMER WORK: Hydrographic Surveying, C. E. 26S—5 weeks.
Railroad Surveying Practice, C. E. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
78	Civil Eng. 75	Hydraulics	4	
78	Civil Eng. 85	Foundations	2	
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
79	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	2	
77	Civil Eng. 55	Physical and Biological Water Analysis		6
77	Civil Eng. 57a	Statistics and Interpretation of Water Analyses }	2	
77	Civil Eng. 57b	Drainage of Marshes and Lowlands }		
90	Mech. Eng. 17	Technical Thermodynamics	2	
95	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	17	15
		Second Half Year		
79	Civil Eng. 90	Railroad Engineering	3	3
79	Civil Eng. 94	Sewers, and River and Harbor Imp.	2	
79	Civil Eng. 96	Principles of Sanitary Science, Public Health and Hygiene	3	
	Law 2	Business Law	2	0
80	Civil Eng. 100	Thesis		6
83	Elect. Eng. 76	Alternating Current Laboratory	1	3
97	Mech. Eng. 76	Mechanical Laboratory	1	3
97	Mech. Eng. 82	Heating and Ventilation	3	
		Total..	15	15

ELECTRICAL ENGINEERING

General Statement

The prescribed course leading to the degree of Electrical Engineer requires four years for its completion, and is designed for the education of those who intend to practice the profession of Electrical Engineering, either as engineers, managers, experts in industrial enterprises or as teachers in colleges or technical schools.

The instruction comprises the important branches of theoretical and applied electricity, also the fundamental and collateral subjects, which have been found by experience to be required by the electrical engineer, as, for example, mathematics, physics, chemistry, drawing, mechanical engineering, including boilers, gas producers, engines, turbines, hydraulic developments, transmission devices and shop work, also such general engineering subjects as construction in wood, masonry, iron and steel.

The graduate in Electrical Engineering is accordingly provided not only with a thorough knowledge of the principles and applications of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for the demands likely to be made upon him in connection with the practice of his profession.

The instruction is by lectures and recitations as well as by laboratory, work-shop and drawing-room practice, with periodic visits to the numerous and important electrical factories, power stations and other establishments in and about New York City.

Equipment

The offices, laboratories, museums and lecture rooms of the Electrical Engineering Department are in the southern portion of the Engineering Building. The laboratories located in the basement contain direct and alternating current machinery and apparatus. The smaller machines are mounted upon heavy tables, thus raising them to a convenient height and affording space for instruments and note-books. To further

simplify the work, the machines have been assembled into unit sets, a motor being provided for each generator, so that the experimental work of one squad of students is entirely independent of that of other squads.

The direct current laboratory contains constant potential and constant current generators, motor-dynamos, as well as various types of stationary and railway motors, aggregating forty machines ranging in capacity from 1 to 35 kilowatts and of standard voltages from 115 to 550. Two 10 and two 5 k.w. generator sets with complete switchboards, carrying many measuring instruments enable various experiments to be performed by the students on the parallel operation of generators. The constant current equipment includes a dynamo, standard switchboard and series lamp circuits. A working standardization equipment for the calibration of all measuring instruments is installed in this laboratory, and prior to any tests the students are required to check their various instruments. About seventy electrical measuring instruments are employed in this laboratory, comprising ammeters and voltmeters with various scale ranges, also speed indicators, transmission and absorption dynamometers. This laboratory is provided with a set of machine and hand tools employed in the repair of the various pieces of apparatus.

The alternating current apparatus, located in the adjoining room, comprises one single-phase alternator of 10 k.w. capacity and two three-phase alternators of 10 and 45 k.w. capacity, respectively; two 10 kilowatt synchronous motors and rotary converts operative on single-phase or two-phase circuits; two single-phase and four polyphase induction motors varying in capacity from 1 to 10 horse-power; constant potential transformers of various capacities; phase transformers for converting two-phase to three-phase currents and *vice versa;* a constant current transformer equipment of 5 kilowatts capacity with its control board, circuits and lamps; an induction regulator of 5 kilowatts and a mercury arc rectifier of the same capacity. Each of the various alternators is provided with its own driving motor, so that the speed, voltage and frequency may be altered as desired. This laboratory equipment includes a complete switchboard for the operation, control, and testing of the rotary converters used as such or as alternators; also a special polyphase circuit measuring board and about forty instruments for the measurement of alternating voltage, current and power. The alternating current ammeters and voltmeters are of various capacities, ranging from fractional values up to 2,000 amperes and 600 volts respectively, also wattmeters up to 1,200 kilowatts range. The instrument equipment further includes several frequency indicators, synchronizers and power factor meters as well as a complete oscillograph and an ondograph for the determination of wave forms, phase relations, etc.

The lecture rooms are provided with direct-current, single-phase and polyphase electrical circuits and projection lanterns so that the lectures may be accompanied by experimental demonstrations and illustrations. The museum contains many pieces of apparatus and parts of machines used in connection with the lectures, such as specimens of pole line insulators, conduit material, rail sections, rail bonds, insulated cables and materials employed in transmission line and electric railway construction. Also various pieces of apparatus employed in telegraphy and telephony; forms of storage battery plates, samples of products obtained by electro-chemical actions, elementary electrical apparatus, etc.; pieces of electrical machinery, such as armature laminations, field and armature coils, commutator sections, brush holders, brushes, insulating materials; small models of various types of generators and motors; numerous forms of incandescent and arc lamps, lamp mechanisms, carbons and electrodes; lightning arresters, line protecting devices and measuring instruments.

On the third floor of the building are located the large instrument laboratory, the departmental drawing-room and the studies of the officers. The laboratory contains tables upon which the various instruments are permanently set up, ready for use. These include many different forms of galvanometers, three ampere balances with scale ranges from .01 to 600 amperes, two dynamometers with ranges of 1 to 200 amperes respectively, a Standard Weston laboratory voltmeter having a range from .01 to 750 volts and a Standard Weston laboratory millivoltmeter with a set of shunts reading up to 500 amperes, Westinghouse precision watt and voltmeters and two very accurate potentiometers. The equipment further comprises apparatus for the exact measurement of resistance, inductance, permeability, hysteresis, and magnetic leakage. This laboratory is supplied with electrical energy from special sources, so that fluctuations do not cause uncertainty in the various measurements. For the direct current work special storage batteries supply potentials up to 250 volts and others have current capacity of 1,000 ampere-hours. For tests requiring small values of alternating currents a special alternator is operated. This laboratory also contains high tension testing apparatus, consisting of two 50,000 volt transformers of 5 and 10 kilowatts capacity respectively, two 10,000 volt transformers of 5 and 10 kilowatts respectively, and one 5,000 volt transformer of 5 kilowatt output. These transformers are supplied with necessary protective and measuring devices and all are designed for operation on 60 cycle circuits. This instrument laboratory is also equipped with several forms of standard integrating and recording watt-hour meters employed in connection with the standardization of consumers' electric meters for the Department of Water Supply, Gas, and Electricity of the City of New York.

The photometric testing laboratory of this Department is situated in the basement of Havemeyer Hall and is equipped with a Lümmer-Brodhun screen photometer for incandescent lamp testing, a Bunsen screen photometer with a meter prover for gas light testing and a Weber photometer, which is adaptable for arc lamp testing or for the determination of general illumination.

COURSE LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

The objects for which the regular four years' course in Electrical Engineering is designed and the education which it is intended to give are fully set forth in the "General Statement" of the Electrical Engineering Department.

The actual curriculum, including the various requirements which must be fulfilled in order to obtain the E. E. degree, are given in the following list of studies for each year, the character of each subject or requirement being explained more fully in the Departmental Statement referred to. The first two years of the course are devoted to the fundamental subjects, including mathematics, physics, chemistry, mechanics, drawing and certain electrical and mechanical engineering subjects which are elementary or introductory in character.

These fundamental and introductory subjects are intended to lay a broad and substantial foundation upon which the more specialized professional instruction of the third and fourth years is based. Even in these later years theoretical subjects, such as thermodynamics and electro-mechanics, are included and given most careful attention.

FIRST YEAR

See page 24

SECOND YEAR

		First Half Year	Hours per week	
See Page			Class	Lab'y
71	Chemistry 65	Quantitative Analysis	2	6
108	Physics 5	Electricity and Magnetism	5	
89	Mathematics 65	Differential and Integral Calculus	5	
89	Mech. Eng. 13	Steam Power Machinery	3	
107	Phys. Educ. B	Gymnasium		2
108	Physics 43	Physical Laboratory		3
109	Physics 105	Physical Measurements	2	
111	Shop Work 13	Machine Work		3
81	Drafting 5	Graphics		3
		Total..	17	17
		Second Half Year		
69	Chemistry 38	Physical Chemistry	2	
73	Chemistry 82	Industrial Chemistry	3	
81	Drafting 6	Graphics	1	3
81	Drafting 8	Structural and Machine Drawing		6
82	Elect. Eng. 2	Elements of Dynamo Electric Mach'y	2	
89	Mech. Eng. 14	Steam Power Machinery	3	
108	Physics 44	Physical Laboratory		3
108	Mechanics 102	Analytical Mechanics	5	
99	Metallurgy 134	Metallurgy of Iron and Steel	2	
107	Phys. Educ. B	Gymnasium		2
111	Shop Work 14	Machine Work		3
		Total..	18	17
		Summer memoir.		

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
76	Civil Eng. 53	Resistance of Materials	5	3
76	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
78	Civil Eng. 77	Hydraulics	2	
83	Elect. Eng. 101	Generator and Motor Practice	3	
85	Elect. Eng. 173	Direct Current Laboratory		6
90	Mech. Eng. 17	Technical Thermodynamics	2	
93	Mech. Eng. 41	Machine Design	1	3
109	Mechanics 105	Thermodynamics	2	
109	Mechanics 107	Theory of Generators and Motor	2	
		Total..	17	15
		Second Half Year		
81	Economics 2	Economics	3	
82	Elect. Eng. 52	Design of Direct Current Machinery	2	3
84	Elect. Eng. 104	Electrical Distribution	3	
85	Elect. Eng. 174	Direct Current Laboratory		3
90	Mech. Eng. 18	Technical Thermodynamics	2	
92	Mech. Eng. 36	Kinematics of Machinery		6
97	Mech. Eng. 76	Experimental Mech. Eng.	1	3
109	Mechanics 108	Theory of Dynamo and Motor	3	
		Total..	14	15
		Summer memoir.		

FOURTH YEAR

		First Half Year		
74	Chemistry 183	Electrochemistry	2	3
83	Elect. Eng. 103	Electric Motors	3	
84	Elect. Eng. 105	Alternating Current Engineering	3	
84	Elect. Eng. 109	Telegraphy	1	
85	Elect. Eng. 175	Alternating Current Lab.	1	6
85	Elect. Eng. 177	Instrument Laboratory	1	6
93	Mech. Eng. 53	Steam Turbines	2	
97	Mech. Eng. 77	Experimental Mechanical Laboratory	1	3
109	Mechanics 109	Theory of Alternators & Transformers	4	
		Total..	18	18
		Second Half Year		
	Elect. Eng.	Preparation of Reports		3
82	Elect. Eng. 54	Design of Alt. Current Machinery	2	2
83	Elect. Eng. 98	Graduation Thesis (Optional)		
84	Elect. Eng. 106	Electric Plants	2	
84	Elect. Eng. 110	Telephone	1	
84	Elect. Eng. 112	Electric Railways	2	
85	Elect. Eng. 176	Alternating Current Laboratory	1	8
94	Mech. Eng. 56	Water Power Installations	1	
95	Mech. Eng. 60	Hydraulic Laboratory		3
96	Mech. Eng. 72	Gas Power Machinery	2	3
109	Mechanics 110	Theory of Variable Currents	3	
		Total..	14	20

MECHANICAL ENGINEERING

General Statement

The regular four-year course, leading to the degree of Mechanical Engineer, offers a thorough basic training in the design, construction, manufacture and operation of all classes of standard and special machinery, and their economic application to railroads, ships, mills, shops, factories and power plants, as well as in the technical and executive management of the manufacturing and transportation industries. To this end the course of instruction is as broad as is consistent with the directness of its purpose. The Mechanical Engineer must not only be grounded in the fundamental scientific basis of his profession, and so trained as to be capable of applying this to both the technical and commercial aspects of industrial problems, but his immediate usefulness upon graduation demands that a considerable portion of the instruction be concerned with the practical application of the principles taught.

The course begins with a thorough training in mathematics, physics and chemistry as a foundation for the appropriate technical work, which is developed along several parallel lines. Applications of these fundamental sciences to the physical properties of the materials of construction, especially the metals and their practical manipulation, lead through the courses in metallurgy, mechanics, resistance of materials, shop processes, the materials testing laboratory, drafting and kinematics to the principles of design, which are fixed by application to the design of machinery for the execution of any sort of process in which machinery is either absolutely essential or more economical than corresponding hand execution of the same process. The principles underlying the performance of machinery are developed by courses in thermodynamics, mechanics and hydraulics with experimental laboratory demonstration and are fixed by analysis of machinery for steam, gas and water power, pumping, compressing, refrigerating, mechanical handling of materials and their most important applications. The instruction in the performance, design and manufacture of machines and power units in the class-room and laboratory, supplemented by visits to power plants and factories, is the basis of the work on the design of plants and mills.

Throughout the instruction the student is thrown as much as possible on his own resources, encouraged to use such knowledge as he possesses, to read standard authorities and to make comparisons between the existing data on various subjects and with the results of theoretical computations. In the experimental work special stress is laid upon this as a means for the development of that initiative, execu-

tive ability and spirit of investigation so necessary for the successful practice of the profession, which is one long series of new problems demanding solution. The commercial and industrial phases of the technical subjects are dwelt upon throughout the entire course of instruction, and particular attention is given to labor and cost systems, works management, economy of manufacture and of power generation, economics and industrial law.

To insure a close contact between the work of the department and the practice of the profession, recognized experts are invited to give lectures on their particular subjects, the regular officers of the department attending and subsequently holding recitations and examinations.

For a list of special lecturers and their subjects see page 8.

In addition to these regular lecturers, a list of non-resident lecturers, who deliver one or more lectures to the students on the work in their respective engineering fields will be found on pages 8, 9 and 10.

The overlapping of the Mechanical Engineering and Electrical Engineering professions makes it desirable that the Mechanical Engineer shall be thoroughly conversant with the ordinary problems of the Electrical Engineer in the generation and distribution of electric current, the characteristics of electrical machinery, and the design and installation of electrical plants. To this end students in this course receive instruction in the department of Electrical Engineering covering these subjects.

Graduate work in Mechanical Engineering is offered to students who have successfully completed the undergraduate course. This graduate work includes the more difficult applications of mechanics and thermodynamics to questions of engineering, as well as special investigations in design, experimental research, and the development of new processes of manufacture. Courses are also offered to students in other departments covering such instruction in Mechanical Engineering as may properly assist in the practice of their respective professions.

Equipment

Besides the usual offices, lecture rooms, drawing rooms and museum, the department is unusually well equipped with experimental laboratory facilities. These laboratories cover a floor space of some 18,500 sq. ft. and contain apparatus valued roughly at $75,000. A fairly full line of instruments for making simple measurements is always available for regular student work, and includes thermometers, pyrometers, barometers, simple and differential manometers, draft gauges, speed counters, tachometers, angular velocity meters, planimeters, Pitot tubes, water meters of piston, rotary and Venturi type, hook gauges, steam and gas meters, steam, gas, coal and oil calorimeters, flue gas analysis apparatus,

scales for weighing and measuring, transmission dynamometers, Prony brakes, indicators of all types, pressure and vacuum gauges, anemometers, mercury columns, and calibrating apparatus for all instruments. Besides these measuring devices there is a large number of pieces of special apparatus for various purposes, such as the testing of carburetors, pressures due to explosion of gas mixtures, rate of flame propagation in explosive mixtures, pressure and temperatures of vaporization of liquid fuels, loss of head in steam, air and water pipes, condensation of steam in pipes, flow of steam or water through orifices and turbine nozzles, capacity of steam traps, flash, chill, density, viscosity and carbonization of oils, friction of bearings, losses in power transmission. These various instruments and pieces of apparatus are grouped and used in connection with a considerable number of machines of standard form. They include a standard gauge Vauclain compound locomotive, mounted on friction wheels equipped with dynamometers. This locomotive is so erected that it can be operated with its own steam, line steam or compressed air, the exhaust passing through an induced draft fan separately driven by a small steam engine. A Reynolds Allis-Corliss triple expansion engine, double eccentric type, is equipped to operate condensing and non-condensing, and is fitted with reheating receivers and may be operated with line steam or high pressure steam from the locomotive boiler. The Corliss engine has a tandem connected to three air cylinders, equipped with Gutermuth flap valves, operating three-stage with water intercoolers. A cross compound steam, two-stage air compressor of the Ingersoll-Sargent type operates in parallel with the other air compressor and with a Westinghouse simple air pump with complete air brake equipment. There is also a belt and a steam driven fan for fan investigations, together with belt and steam driven centrifugal pumps for corresponding investigation on centrifugal action of water. Besides the steam engines mentioned there are also a Westinghouse two-cylinder, single-acting; McIntosh and Seymour automatic; Sweet straight-line simple engine, besides some smaller reciprocating units, and a De Laval steam turbine, all piped to condensers for efficiency tests on wet, dry or superheated by a Foster superheater separately fired. The steam used by the engines and pumps is measured by any one of three surface condensers, Wheeler, Worthington, Allis, each with its own air and circulating pumps. The steam equipment includes also typical injectors, steam traps, feed water heaters, separators, reducing valves, safety valves, back pressure valves and other ordinary steam auxiliaries and specialties. The hydraulic work is well provided for by two large 20,000-lb. measuring tanks, fitted with swinging guide-bucket for continuous flow measurements, receiving the discharge from all the hydraulic apparatus; water channels of rectangular, trapezoidal and triangular cross section, rectangular and trapezoidal weirs, fitted to

several weir tanks, of iron and wood, three impulse water wheels, one small turbine, hydraulic rams, simple, single and duplex steam pumps, direct acting and flywheel, compound Blake pump, single acting, direct acting triple expansion duplex, low pressure Worthington pump of large capacity and low head, separately steam driven centrifugal Lawrence pump, belt driven centrifugal pump, a high pressure pump and accumulator of the Worthington type for 1500 lbs., and a second for 5000 lbs. pressure. Two hot air engines, and several internal combustion engines, including the Nash, fitted to operate on various fuels, a Hornsby-Akroyd and a Mietz and Weiss oil engine, an old and a new style Otto, an International Harvester, a Daimler boat engine are equipped for gas engine test and investigation work of great variety. From time to time other machines are secured for short periods of time for testing purposes. For the study of refrigeration there is installed a small Brunswick ammonia compression ice-making and refrigerating unit, motor driven, and a larger De La Vergne steam-driven, ice-making plant.

COURSE LEADING TO THE DEGREE OF MECHANICAL ENGINEER

All the subjects leading to the degree of Mechanical Engineer are listed in the following table, together with the year and term in which they are given. The first two years are devoted to essential preparatory and fundamental subjects, mathematics, chemistry, physics, analytical mechanics and drawing which are co-ordinated with kinematics, elementary design, shop work and the elements of electrical and steam engineering. In the third year there are developed the basic principles of thermodynamics, resistance of materials and hydraulics, which are fixed in the mind of the student by drill in the drafting room by design courses, in the laboratory by experiments and tests and in class by analysis of standard mechanical and electrical machinery. The fourth year is devoted to a detailed treatment of gas and steam engine design, standard water turbine characteristics and the essential relations between units constituting power plants and factories. Special attention is here paid to the economics of mechanical engineering by courses in industrial law, economics and works management. Throughout the course the aim is to develop clear conceptions of underlying principles, habits of independent thought and orderly mental procedure applicable to any sort of Mechanical Engineering problems rather than to the memorization of isolated facts. The training given not only fits the student to take up the design of machinery and the perfection of processes of doing things by mechanical means, but also to take ultimately a leading place in the management of the manufacturing and transportation industries.

FIRST YEAR

See page 33

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
81	Drafting 7	Structural Drafting		3
108	Physics 5	Electricity	5	
89	Mathematics 65	Calculus	5	
89	Mech. Eng. 11	Steam Power Machinery	3	
94	Mech. Eng. 59	Empiric Design	2	
107	Phys. Educ. B	Gymnasium		3
108	Physics 43	Physical Laboratory		2
110	Shopwork 1	Pattern Making		3
92	Mech. Eng. 35	Kinematics		6
				3
		Total..	15	20
Second Half Year				
108	Physics 44	Physical Laboratory		3
73	Chemistry 82	Industrial Chemistry	3	
82	Elect. Eng. 2	Elements of Electrical Engineering	2	
89	Mech. Eng. 12	Steam Power Machinery	3	3
92	Mech. Eng. 36	Kinematics		3
108	Mechanics 102	Analytical Mechanics	5	
99	Metallurgy 134	Iron and Steel	2	
107	Phys. Educ. B	Gymnasium		2
110	Shopwork 2	Moulding and Foundry Practice		3
110	Shopwork 12	Forging		6
		Total..	15	20

SUMMER WORK: Shop Work 10s. 125 hours in College shops; Mech. Eng. 94s. 6 weeks practical work in shops and drafting rooms of manufacturing establishments, with report. A total of 9 weeks.

THIRD YEAR

See Page		First Half Year	Hours per week Class	Lab'y
76	Civil Eng. 53	Resistance of Materials	5	3
82	Elect. Eng. 73	Direct Current Laboratory		3
83	Elect. Eng. 101	Dynamo and Motor Practice	2	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
91	Mech. Eng. 31	Standard Tests	1	3
92	Mech. Eng. 39	Machine Design	1	6
109	Mechanics 105	Thermodynamics	2	
110	Shopwork 11	Machine Shop		6
		Total..	13	21
		Second Half Year		
76	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
78	Civil Eng. 78	Hydraulics	2	
82	Elect. Eng. 4	Electric Distribution	2	
90	Mech. Eng. 18	Engineering Thermodynamics	2	
91	Mech. Eng. 32	Standard Tests	1	3
92	Mech. Eng. 40	Machine Design	2	6
94	Mech. Eng. 54	Shop Processes	2	
95	Mech. Eng. 62,	Refrigerating Machinery	1	
95	Mech. Eng. 64,	Air Machinery	2	
96	Mech. Eng. 66,	Elevators and Conveyors	1	
96	Mech. Eng. 70,	Pumping Machinery	2	
95	Mech. Eng. 60	Hydraulic Laboratory	1	3
100	Metallurgy 156	Metallographic Laboratory		
		Total..	18	15

SUMMER WORK: Mech. Eng. 96s. 6 weeks practical work in power plant, with report

FOURTH YEAR

		First Half Year		
83	Elect. Eng. 75	Alternating Current Laboratory	1	3
83	Elect. Eng. 103	Electric Power	2	
84	Elect. Eng. 105	Electrical Distribution	2	
90	Mech. Eng. 19	Engine Design	3	6
91	Mech. Eng. 25	Steam Power	3	6
91	Mech. Eng. 33	Standard Tests	2	3
93	Mech. Eng. 53	Steam Turbines	2	
		Total..	15	18
		Second Half Year		
88	Law 2	Business Law	3	
81	Economics 2	Economics	3	
90	Mech. Eng. 20	Engine Design	3	6
90	Mech. Eng. 22	Gas Power Machinery	4	3
93	Mech. Eng. 46	Water Power Machinery	3	
93	Mech. Eng. 52	Organization and Management	2	
96	Mech. Eng. 68	Shops and Factories	2	3
		Total..	20	12

CHEMISTRY

General Statement

The regular four-year courses of instruction herein shown are designed for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges and scientific schools, or as chemists or managers in manufacturing and other industrial enterprises.

There are two courses offered, leading to the degrees of Chemist and Chemical Engineer respectively.

Equipment

In Havemeyer Hall the Chemical Department is provided with space for its museum, lecture-rooms, and laboratories, and every convenience has been provided for both the instructors and students working in the general or special courses.

There are five chemical lecture-rooms, all fully supplied with apparatus and instruments, the desks being equipped with pneumatic troughs, gas, pressure, exhaust, and electricity. The large chemical lecture-room on the ground floor contains 315 seats.

The Chandler Museum of General Inorganic and Organic Chemistry and of the Chemical Arts, a large room occupying the whole left wing of the ground floor, contains the elements and all their more important compounds, inorganic and organic; materials and products illustrating the chemical arts, and numerous models, pictures, and diagrams.

The Qualitative Laboratory has 112 desks, each divided into two sections, and each thoroughly equipped.

The Quantitative Laboratory has eighty-eight desks. Attached to the main laboratory is a large, well-equipped balance-room, containing accurate balances, and special rooms, provided with apparatus for gas, water, food, and electrolytic analysis.

The Assay Laboratory is provided with crucible and muffle furnaces, coal, gas, and gasoline, for the fire assay of ores; also with crushing, pulverizing, and sampling machinery, balance-room, storeroom, and thirty-six well-equipped working desks. It also contains all the apparatus necessary for the wet assay of silver bullion and for laboratory tests of ores.

The Organic Laboratory has forty large desks, provided with gas, water, exhaust, and electricity, and has special rooms for balances, pressure ovens, glass-blowing, and combustions.

The Laboratory of Industrial Chemistry, for the instruction of students in practical operations and the solution of problems in connec-

tion with the chemical industries, is equipped for the manufacture of pure chemicals from their raw materials on a large scale, with batteries of steam evaporators, and with steam stills, centrifugals, filter presses, crushers, and the like. It includes a dyeing laboratory with a large stock of dye-stuffs, and with the regular equipment for the practical testing of dyes, including a calico-printing machine. Connected with it is a photometer-room, containing a new and complete outfit for the practical testing of illuminants.

It also includes a laboratory for chemical microscopy, newly equipped with microscopes, polarized light apparatus, camera lucidas, etc., for the practical use of the microscope in chemical operations.

A new Laboratory for Applied Electrochemistry has been provided. The equipment consists of special motor-dynamos, one of which furnishes direct current at low voltages to the students' desks for general electrolytic work; the other provides heavy alternating current to the electric furnace room; this room is furnished with all appliances for electric furnace work. The students' desks are fitted with special switchboards and measuring instruments, and the laboratory has been arranged for carrying on research work in all branches of electrochemistry.

The Laboratory of Physical Chemistry is well equipped with the most recent apparatus adapted to a wide range of experimental work in the branches of heat, light, and electricity as applied to chemical problems.

The Chemical Library in Havemeyer Hall is supplied with an extensive collection of chemical books and journals, and is open from 9.00 A.M. to 5.00 P.M., and during the session of the University from 8.00 to 11.00 P.M.

COURSE LEADING TO THE DEGREE OF CHEMICAL ENGINEER

The course in chemical engineering, as will be seen, is designed to educate chemists with a sufficient amount of engineering to fit them to take charge of chemical works which depend upon the application of engineering methods and appliances to the production of chemical products. This requires a knowledge of mechanical engineering, electrical engineering, hydraulics, mechanical drawing, shopwork, etc., as well as a thorough knowledge of chemistry in all its branches.

FIRST YEAR

See page 33

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
70	Chemistry 41	Organic Chemistry	2	
71	Chemistry 163	Quantitative Analysis	4	12
108	Physics 5	Electricity	5	
89	Mathematics 65	Differential Integral Calculus	5	
103	Mineralogy 15	Physical Laboratory		3
108	Physics 43	Determinative Mineralogy		3
107	Phys. Educ. B	Gymnasium		2
		Total..	16	20
Second Half Year				
70	Chemistry 42	Organic Chemistry	2	
73	Chemistry 82	Industrial Chemistry	3	
71	Chemistry 164	Quantitative Analysis	4	12
82	Elect. Eng. 2	Elements of the Dynamo	2	
108	Mechanics 102	Analytical Mechanics	5	
103	Mineralogy 16	Determinative Mineralogy		3
108	Physics 44	Physical Laboratory		3
107	Phys. Educ. B	Gymnasium		2
		Total..	16	20

SUMMER WORK: Chemistry 80a, Chemistry s69. Shopwork 18s (8), 3 weeks in June

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
76	Civil Eng. 53	Resistance of Materials	5	3
73	Chemistry 83	Industrial Chemistry	3	
73	Chemistry 171	Organic and Sanitary Analysis	4	9
89	Mech. Eng. 13	Steam Power Machinery	3	
94	Mech. Eng. 59	Empiric Design	2	3
99	Metallurgy 131	Iron and Steel (half term)	1	
100	Metallurgy 141	Electro-metallurgy (half term)	1	
		Total..	19	15
		Second Half Year		
76	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
73	Chemistry 84	Food Chemistry	3	
70	Chemistry 150	Organic Chemistry	2	9
82	Elect. Eng. 72	Direct Current Laboratory		3
82	Elect. Eng. 4	Electric Distribution	2	
89	Mech. Eng. 14	Steam Power Machinery	3	
96	Mech. Eng. 70	Pumps and Pumping Machinery	2	
88	Law 2	Business Law	2	
		Total..	14	15

SUMMER WORK: Chemistry 80b. Chemical Factory work with Memoir—6 weeks.

FOURTH YEAR

		First Half Year		
78	Civil Eng. 77	Hydraulics	2	
73	Chemistry 89	Industrial Laboratory		6
74	Chemistry 197	Chemical Factory Machinery	3	
69	Chemistry 121	Physical Chemistry	3	2
90	Mech. Eng. 17	Technical Thermodynamics	2	
92	Mech. Eng. 37	Machine Design	1	6
97	Mech. Eng. 77	Experimental Engineering Laboratory	1	3
98	Metallurgy101,111	Introduction and Metallurgy of Copper	3	
		Total..	15	17
		Second Half Year		
74	Chemistry 198	Chemical Factory Organization	3	
69	Chemistry 122	Physical Chemistry	3	
74	Chemistry 184	Practical Electro-Chemistry	2	3
	Chemistry	Thesis		9
90	Mech. Eng. 18	Technical Thermodynamics	2	
93	Mech. Eng. 52	Works Management	2	
97	Mech. Eng. 76	Experimental Engineering Laboratory	1	3
98	Metallurgy 172	Laboratory		2
99	Metallurgy 122	Metallurgy of Gold, Silver, Lead, Zinc	3	
		Total..	16	17

COURSE LEADING TO THE DEGREE OF CHEMIST

The course in chemistry includes not only all branches of theoretical, analytical, and industrial chemistry, but also collateral sciences, such as mathematics, mechanics, physics, mineralogy, metallurgy, mechanical and electrical engineering, and drawing, which have been found by experience to be required by the professional chemist. It is the intention to provide the graduate not only with a thorough knowledge of the principles and practice of chemistry in all its branches, but with such a broad and liberal education in the collateral sciences as will prepare him for every demand that will be likely to be made upon him in connection with his profession or in the pursuit of investigation.

FIRST YEAR

See page 33

SECOND YEAR

		First Half Year	Hours per week	
See Page			Class	Lab'y
69	Chemistry 21	Elementary Physical Chemistry	2	
70	Chemistry 41	Elementary Organic—Lecture Course	2	
71	Chemistry 163	Quantitative Analysis	4	12
108	Physics 5	Elements of Electrical Engineering	5	
89	Mathematics 65	Differential and Integral Calculus	5	
103	Mineralogy 15	Determinative Mineralogy		3
107	Phys. Educ. B	Gymnasium		2
		Total..	18	17
		Second Half Year		
69	Chemistry 22	Elementary Physical Chemistry	3	2
70	Chemistry 42	Elementary Organic—Lecture Course	2	
73	Chemistry 62	Industrial Chemistry—General Course	3	
71	Chemistry 164	Quantitative Analysis	4	12
82	Elect. Eng. 2	Elements of Dynamo	2	
108	Mechanics 102	Analytical Mechanics	5	
103	Mineralogy 16	Determinative Mineralogy		3
107	Phys. Educ. B	Gymnasium		2
		Total..	19	19

SUMMER WORK: Chemistry 80a—Memoir.

THIRD YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
73	Chemistry 83	Industrial Chemistry	3	
73	Chemistry 91	Chemical Microscopy		4
69	Chemistry 101	Advanced Inorganic	2	
72	Chemistry 171	Organic and Sanitary Analysis	4	15
74	Chemistry 183	Industrial Electrochemistry	1	
89	Mech. Eng. 13	Steam Power Machinery	3	
99	Metallurgy 131	Iron and Steel (half term)	1	
100	Metallurgy 141	Electro-metallurgy half-term	1	
		Total..	15	19
Second Half Year				
73	Chemistry 84	Food Chemistry	3	
73	Chemistry 88	Industrial—Laboratory Course		6
73	Chemistry 92	Chemical Microscopy		4
73	Chemistry 102	Advanced Inorganic Chemistry	2	
73	Chemistry 170	Assaying	2	9
74	Chemistry 184	Industrial Electrochemistry	1	3
89	Mech. Eng. 14	Steam Power Machinery	3	
		Total..	11	22

SUMMER WORK: Chemistry 80b—Memoir.

FOURTH YEAR

First Half Year				
69	Chemistry 7	Inorganic Chemistry—or	Elective or taken from afternoons	(2)	
69	Chemistry 23	Physical Chemistry—or			
73	Chemistry 93	Electro Chemistry—or			
74	Chemistry 95	Industrial Chemistry—or			
70	Chemistry 143	Organic Chemistry—or			
72	Chemistry 167	Adv. Inorg. Anal. Chem.—or			
72	Chemistry 173	Adv. Org. Anal. Chemistry			
73	Chemistry 89	Industrial Chemistry—Lab. Practice			3
69	Chemistry 121	Physical Chemistry		3	2
70	Chemistry 141	Organic Chemistry—General Course		5	12
98	Metallurgy 101, 111	Introduction and Metal'gy of Copper		3	
		Total..		13	17
Second Half Year					
69	Chemistry 122	Physical Chemistry		3	
70	Chemistry 142	Organic Chemistry—General Course		5	
99	Metallurgy 122	Lead, Silver, Gold and Zinc		3	
	Thesis—			2	15
69	Chemistry 8	Inorg. Chemistry—or			
69	Chemistry 24	Physical Chemistry—or			
74	Chemistry 94	Electro-Chemistry—or			
74	Chemistry 96	Industrial Chemistry—or			
70	Chemistry 144	Organic Chemistry—or			
72	Chemistry 168	Adv. Inorg. Anal. Chemistry—or			
72	Chemistry 174	Adv. Org. Anal. Chemistry—or			
72	Chemistry 176	Food Chemistry			
		Total..		16	15

COURSES OF INSTRUCTION

Arranged Alphabetically by Departments

ASTRONOMY

105—Geodesy. 3 hours. Professor S. A. MITCHELL.

Brief history of geodetic operations and description of theodolites, base apparatus, and other instruments used in geodetic work, including their adjustment and use. Text-book: Wilson's *Topographic Surveying.*

106—Geodesy. 1 hour and 1 laboratory period. Professor S. A. MITCHELL.

The applications of practical astronomy to geodetic surveying, and training in methods of accurate computation. Text-book: Wilson's *Topographic Surveying.*

107—Geodesy. Professors JACOBY and S. A. MITCHELL, with Assistants.

Summer Course in Practical Geodesy: Given at Camp Columbia, Morris, Conn.

Pre-requisite for all courses: Mathematics of first two years.

BACTERIOLOGY

101—Sanitary Bacteriology. 2 hours and 2 afternoons a week for nine weeks. Professor HISS and Assistants.

Practical instruction in Bacteriology and Hygiene. A short course for Sanitary Engineering Students, adapted from and covering the more important topics treated in Courses 51 and 201. The course opens with the study of the relationship of bacteria to other micro-organisms. It embraces the methods of staining, examining, and cultivating. The student is taught by practical exercises the methods of separating one species of bacteria from another, and the series of biological characters used in identification of the various forms. The general and special relationship of micro-organisms to disease is considered. Finally some of the hygienic aspects of bacteriology are studied by experiments in the sterilization of infectious material, disinfection of the hands, and by practice in the biology of air, water, milk, and other foods, and soil analysis. For students in Sanitary Engineering.

Pre-requisite: Chemistry, 65, 92*a*.

BOTANY

7—Growth and Character of Timber. 1 hour and 1 afternoon. Professor CURTIS and Dr. DARLING.

Growth of the tree, character and arrangement of its tissues; relation of moisture to strength of timber; the deterioration, preservation, distribution and identification of lumber.

Second year for Civil Engineering students.

CHEMISTRY

Courses

The following courses in Chemistry are included in the programs of study of the Schools of Mines, Engineering and Chemistry. For other courses offered see the *Announcement of the Division of Chemistry.*

Inorganic Chemistry

3-4—General Inorganic Chemistry. 2 lectures and 1 recitation. Professor SMITH.

Introduction. Laws of chemical combination, history, occurrence, preparation, and properties of the elements and their principal compounds.

Pre-requisite: Course Chem. A or Entrance Examination in Chemistry.

7-8—Inorganic Chemistry. 2 hours lectures or conferences throughout the year and 5 afternoons laboratory the second half-year. Professor SMITH.

Designed for fourth-year students in the course of chemistry selecting a thesis in inorganic chemistry.

101-102—Advanced Inorganic Chemistry. 2 lectures. Professor SMITH.

Including the origin and development of the periodic law, and the history and properties of the rare elements.

Pre-requisite: Courses 3-4 and 61-62.

Summer Courses

For details, see the *Announcement of the Summer Session.*

S1 (S6)—General Chemistry. 5 hours lectures, 12 hours laboratory work, and 2 hours recitations. Mr. WILLIAMS and Mr. WHITMAN.

Extension Teaching, Evening Courses

For details see the *Announcement of Extension Teaching.*

eA1-eA2—General Chemistry, College Course. Elementary course for students beginning the study of chemistry. 2 lectures, 1 recitation and 2 hours laboratory practice, counting as 4 points each half year. This course is a duplication of the day course **A1-A2.** Dr. NEISH.

Text-book: Smith's *General Chemistry for Colleges.*

Physical Chemistry

21-22—Elementary Physical Chemistry. 2 hours lectures and recitations first half-year and 3 hours second half-year, with laboratory work 15 afternoons second half-year (equivalent to 1 afternoon throughout the half-year). Professor MORGAN and Assistant.

Text-books: Portions of Morgan's *Physical Chemistry for Electrical Engineers* and Ostwald's *Physico-Chemical Measurements.*

Pre-requisite: Course 3-4 and Physics 3-4.

121-122—Physical Chemistry. 3 hours lectures and recitations during the entire year, and 15 afternoons, equivalent to 1 afternoon a week, laboratory during the first half-year. Professor MORGAN and Assistant.

A course treating of the states of aggregation, solution, and ions in analytical chemistry, thermo-chemistry, chemical mechanics, and electro-chemistry. Text-books: Morgan's *Elements of Physical Chemistry,* and Ostwald's *Physico-chemical Measurements.*

Pre-requisite: Course 3-4 and 61-62, Physics 3-4 and Mathematics 5-6.

38—Theoretical Electro-chemistry. 2 hours lectures and recitations. Professor MORGAN.

Text-book: Portions of *Morgan's Physical Chemistry for Electrical Engineers.*
Pre-requisite: Course 3-4 and 65, Physics 3-4, and Mathematics 5-6.

23-24—Physical Chemistry. 2 hours in lectures or conferences throughout the year, and 5 afternoons laboratory during the second half-year. Professor MORGAN.

Designed for four-year students in the course of chemistry, selecting a thesis in physical chemistry.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s138—Elementary Physical Chemistry. 5 hours. Professor MORGAN.

Research. The laboratory is open to properly qualified students for research under the direction of Professor MORGAN.

Organic Chemistry

41-42—Organic Chemistry, Elementary Lecture Course. 2 hours. Dr. NELSON.

An introductory course, which can be taken with advantage by college students and by those expecting to enter the medical course. Instruction given on such important classes of compounds as the hydrocarbons, alcohols, ethers, organic acids, fats, waxes, soaps, cyanides, sugars, carbohydrates, alkaloids, coloring matters, drugs, perfumes, and the like. The lectures will be liberally illustrated by material from the Chemical Museum and by experimental demonstration. Text-book: Perkin & Kipping's *Organic Chemistry.*

Pre-requisite: Course 3-4. It is urged that, if possible, laboratory work, Course 43-44, be taken with this elementary lecture course.

43-44—Organic Chemistry, Elementary Laboratory Course. 8 hours. Dr. NELSON and Mr. FISHER.

A study of the typical methods for preparation and the typical reactions of the important classes of organic compounds. The laboratory work may be varied according to the needs of the student. Text-book: Gattermann's *Practical Methods of Organic Chemistry.*

Pre-requisite or parallel: Courses 3-4 and 41-42.

141-142—Organic Chemistry, General Course. 3 lectures and 2 recitations a week for one year, and 4 afternoons laboratory the first half-year. Professor BOGERT, Dr. NELSON and Mr. FISHER.

A more comprehensive treatment of the subject, including a discussion of all the important classes of organic compounds. In the laboratory a large number of typical organic substances are prepared synthetically, and instruction given in the methods of qualitative and ultimate organic analysis. In addition students taking the course as a major for A.M. are required to submit an essay upon some special line of practical work assigned by the instructor. Text-books: Holleman's *Organic Chemistry,* Gattermann's *Practical Methods of Organic Chemistry.*

Pre-requisite: Courses 3-4, 21-22, and 161-162.

143-144—Organic Chemistry, Conferences. 2 hours. Professor BOGERT.

Presentation and discussion of recent important investigations in the field of organic chemistry.

Required, together with 5 afternoons laboratory practice the second half-year, of all fourth-year students in the School of Chemistry selecting a thesis in organic chemistry. Pre-requisite or parallel: Course 141-142.

150—Advanced Organic Chemistry for Chemical Engineering Students. 2 lectures and 3 afternoons. Dr. NELSON and Mr. FISHER.

The study of organic compounds and reactions with particular reference to their relation to commercial products and manufacturing processes.

Pre-requisite: Course 41-42 or its equivalent. Required of all third-year chemical engineering students.

151-152—Advanced Organic Chemistry, Laboratory Course. 2 afternoons. Professor BOGERT, Dr. NELSON and Mr. FISHER.

The synthesis and study of any one of such important groups of organic compounds as (*a*) dyestuffs, (*b*) essential oils, (*c*) alkaloids, (*d*) synthetic drugs and organic substances of special interest to the medical profession, or similar groups to be selected by conference with the instructor.

For chemical engineers electing a thesis in organic chemistry, 3 afternoons, second half-year. Minor for A.M. or Ph.D. or major for A.M., depending upon amount of work performed.

Pre-requisite: Courses 3-4, 41-42, and 43-44.

Summer Courses

S41-42—Organic Chemistry, Elementary Lecture Course. 10 hours. Dr. NELSON and Assistant.

S43-44—Organic Chemistry, Laboratory Course. Dr. NELSON and Assistant.

Research. The laboratory is open to properly qualified students for research under the direction of Dr. NELSON and Assistant.

Analytical Chemistry

61 or 62—Qualitative Analysis. 4 hours and 5 afternoons. Professor BEANS, Dr. ZANETTI, Dr. MOORE.

Theory and practice of qualitative analysis based upon the principles of physical chemistry. Text-book: Böttger's *Qualitative Analysis.*

Pre-requisite: Course 1 or 2 or its equivalent.

65—Quantitative Analysis, Inorganic, Short Course. 2 hours and 2 afternoons. Professor METZGER and Dr. JOÜET.

The analyses included in this course are: Magnesium sulphate, potassium alum, coal, iron ore, copper, zinc, alkalimetry, acidimetry, and flue gas. Text-books: Miller's *Notes on Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

Pre-requisite: Courses 3-4 and 61 or 62.

66—Quantitative Analysis, Inorganic. 3 hours and 4 afternoons. Professor METZGER, Dr. JOÜET and Assistants.

The analyses included in this course are: Magnesium sulphate, potassium alum, iron-ammonium alum, coal, iron ore, pig iron, spiegel, zinc ore, limestone, slag, copper, lead, arsenic, antimony, ores, and flue gas. Text-books: Miller's *Notes on Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

Pre-requisite: Courses 3-4 and 61 or 62.

161-162—Quantitative Analysis, Inorganic. 1 hour and 8 hours laboratory. Professor METZGER and Assistant.

Text-book: Talbot's *Quantitative Analysis.*

Pre-requisite: Courses 3-4 and 61 or 62.

163-164—Quantitative Analysis. 4 hours and 4 afternoons. Professor METZGER and Dr. JOÜET.

The classroom work includes not only the methods applied in the laboratory, but discussions of quantitative separations from a theoretical standpoint, and chemical calculations. Text-books: Treadwell's *Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

The analyses included in this course are: Magnesium sulphate, sodium or other chloride, potassium alum, iron ammonium alum, coal, iron ore, pig iron, spiegel, limestone, slag, feldspar, ores of zinc, copper, nickel, lead, chromium, arsenic, antimony, alloys, rocks, gas analysis, etc.

Pre-requisite: Courses 3-4 and 61 or 62.

167-168—Advanced Inorganic Analysis. 2 hours. Professor METZGER.

Laboratory practice 5 afternoons during the second half-year for students in the course of Chemistry, who elect thesis work in inorganic analytical chemistry.

In the first half-year, systematic volumetric analysis and technical analytical methods connected with iron, steel, copper, lead and zinc metallurgy. In the second half-year, rock analysis and the analytical chemistry of the rare elements.

Pre-requisite or parallel: Chemistry 101-102, 121-122, 163-164.

171—Organic and Sanitary Analysis. 4 hours and 5 afternoons for chemists, 3 afternoons for chemical engineers, 3 to 5 afternoons for graduate students. Professor SHERMAN and Assistant.

The lectures include general and industrial organic analysis, food and fertilizer analysis and inspection, examination of drinking water. Special attention is given to the interpretation of the analytical results. Text-books: Sherman's *Methods of Organic Analysis* and Mason's *Examination of Water;* for reference, Richards and Woodman's *Air, Water and Food.*

The analyses included in this course are: Acidimetry and alkalimetry, alcohol, glycerol, formaldehyde, sugars, cream of tartar, milk, butter, fatty and lubricating oils, soap, paint, asphalt, fertilizers, and the sanitary analysis of water.

Pre-requisite: Courses 3-4, 61-62, 161-162 and 41-42.

173-174—Advanced Organic Analysis. 2 hours. Professor SHERMAN.

Laboratory work during the second half-year 5 afternoons for fourth-year students in the Chemistry course who elect thesis work in organic analytical chemistry or food chemistry.

The analytical chemistry of proteins and their derivatives, alkaloids, tannins and fibres; plant analysis; advanced methods in food analysis; measurement of the activity of enzymes and the digestibility and nutritive value of food; systematic review of organic analysis.

Pre-requisite or parallel: Course 171 (or equivalent work in 271-272).

176—Chemistry of Food and Nutrition. 3 hours. Professor SHERMAN.

The chemistry and functions of the foodstuffs; the composition and nutritive values of food materials; the amounts of food required in nutrition; methods of determining the nutritive values of special foods and the effects of adulteration; food legislation and inspection; standards of purity for food products; normal and abnormal variations in composition.

69 or 170—Assaying. 2 lectures or recitations and 3 afternoons first half-year for mining engineers and metallurgists; second half-year for chemists. Professor HALL.

Ores and metallurgical products. Text-book: Fulton's *Manual of Assaying.*

The assays included in this course are: Preliminary (reagents, etc.); lead ores; gold and silver ores, pure and impure, including galena, stibnite, arsenopyrite, blende, pyrite, tellurides, etc.; mattes and tailings; corrected assays and extraction tests; gold, silver, and lead bullions.

Pre-requisite: Courses 3-4, 61-62, and Mineralogy 1-2 or 7-8.

160—Special Methods of Assaying Ores, Alloys, and Furnace Products. 8 hours conferences and laboratory. Professor HALL.

Comparison of methods and determination of losses.

Pre-requisite: Courses 3-4, 61-62, 69, and Mineralogy 1-2 or 7-8.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s61-62—Qualitative Analysis. 10 hours lectures and conferences, and 30 hours laboratory work a week. Professor BEANS and Assistant.

s69 or 170—Assaying. 5 hours lectures and 30 hours laboratory work a week. Professor HALL.

Required of Chem. Engineers.

s161-162—Quantitative Analysis. 5 hours lectures and 30 hours laboratory work a week (accepted for Course 65). Dr. JOÜET.

sF—Chemistry of Nutrition. 5 hours lectures. Professor SHERMAN.

s171a—Organic and Sanitary Analysis. Conferences and laboratory. Professor SHERMAN and Assistant.

s171b—Food Analysis and Inspection. Professor SHERMAN.

Research. The laboratory is open to properly qualified students for research, in organic analytical chemistry or the chemistry of foods, under the direction of Professor SHERMAN.

Industrial Chemistry

81-82—Industrial Chemistry, General. 3 hours lectures. Professor WHITAKER and Dr. KRESS.

Air; water; sulphur; sulphuric acid; nitric acid; hydrochloric acid; alkali industries; potash; artificial gases and natural gas; petroleum and its products; cement; paints and varnishes; soaps; ceramics; glass; explosives; fuels; structural materials.

Pre-requisite: Courses Chemistry 3-4.

83—Industrial Chemistry, Advanced Course. 3 hours. Professor WHITAKER and Dr. KRESS.

Textiles; tanning; glue and gums; India rubber and plastics; celluloid; explosives; artificial fibers; paints, oils, varnishes; paper; photography, etc.

Pre-requisite: Courses Chemistry 3-4 and 81-82.

84—Food Chemistry. 3 hours. Professor SHERMAN.

The general principles of food chemistry and food legislation and the chemical technology and control of the more important food industries; milk and its products; meat products; edible fats and oils; grain products; starch, glucose, sugar; fruit products; fermentation; etc.

Pre-requisite: Chemistry 3-4 and 81-82.

88—Industrial Chemistry, Laboratory Practice. 3 afternoons. Professor WHITAKER and Dr. KRESS.

Preparation of inorganic chemicals, including the preparation and purification of chemical reagents, pigments, and salts of the rare as well as of the common metals.

Pre-requisite: Courses 3-4, 61-62.

89—Industrial Chemistry, Laboratory Practice. 1 afternoon. Dr. KRESS.

Special applications: Textile industry, vegetable and animal fibres, bleaching, dyeing, and calico printing. Including instruction in the use of the microscope.

Pre-requisite: Course 3-4, 61-62, 147-148.

95-96—Industrial Chemistry. 2 hours throughout the year, and 5 afternoons in the laboratory during the second half-year. Professor WHITAKER and Dr. KRESS.

Designed for fourth-year students in the course of chemistry selecting a thesis in industrial chemistry.

197—Chemical Factory Apparatus and Machines. 3 hours. Professors WHITAKER and THOMAS.

To cover the construction and use of the apparatus and machinery of chemical factories.

198—Chemical Factory Management. 3 hours. Professor WHITAKER.

Relations of the chemist to the various phases of making and marketing chemical products. Sales organization and methods; transportation of products and materials; purchase of supplies; warehousing and stocks; manufacturing organization; equipment; process; operation; cost keeping and accounting; process improvements; product improvements; factory economics; labor; insurance; fire and accident protection; finance; administration.

80a—Factory Inspection and Summer Memoir. Professor WHITAKER and Dr. KRESS.

Visiting and inspection of chemical works of special interest in and near New York City, such as gas works, petroleum refineries, sugar houses, dyeing and calico-printing establishments, paint and varnish factories, soap, candle and oleomargarine works, paper mills, and plants for the purification of water and sewage.

Required of all second-year students in the courses of chemistry and chemical engineering. The visits to factories are made during the two weeks following the final examinations.

80b—Factory Inspection and Summer Memoir. Professor WHITAKER and Dr. KRESS.

Similar to 80a, but including working plans and full estimate of cost of a chemical laboratory, according to outlines assigned to each student.

Required of all third-year students in the course of chemistry.

Required, without memoir, of all third-year students in the course of chemical engineering.

Electro-Chemistry

93-94—Electro-Chemistry. 2 hours throughout the year, and 5 afternoons during the second half-year. Professor TUCKER.

Designed for fourth-year students in the course of chemistry or chemical engineering selecting a thesis in electro-chemistry.

181 or 182—Practical Electro-Chemistry. 10 hours. Professor TUCKER.

Electro-plating, influential factors in electrolysis, electrolysis with molten electrolytes, the use of diaphragms, electrolytic preparations, electric furnace practice.

Pre-requisite: Courses 3-4, 61-62, 65.

183-184—Industrial Electro-Chemistry. 1 hour and 14 afternoons. Professor TUCKER.

Theory and practice of electrolysis or electro-deposition, electric smelting and refining, primary and secondary batteries, production, preparation and purification of chemicals and metals.

Pre-requisite: 3-4, 65.

CIVIL ENGINEERING

2—Theory of Surveying. Lectures and recitations, 2 hours. Professor LOVELL, Mr. FINCH and Assistants.

Methods of measuring angles and distances. Cumulative and compensating errors, and corrections to be applied. Limits of precision. Use, care, and adjustment of the engineer's transit, level, and compass. Magnetic declination and variation. Local attraction. Relocation of old lines by compass bearings. Erroneous standards. Surplus and deficiency. Significance of monuments. Traverses; computations of area and error of closure. Laying out and dividing up land. System of public land surveys. Topographic surveys; transit stadia and plane table methods. Triangulation. City surveying, subdivision and resurveys. Interpretation of deed descriptions. Text-book: Tracy's *Plane Surveying*.
For all first-year students in Chemistry.

15—Surveying between the First and Second Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Survey 1 includes pacing and chaining, ranging out lines, contouring with hand level, mapping. *Survey 2* consists of the adjustment of the level and in running a line of differential levels. Note book and report. *Survey 3* consists of the adjustment of the transit, angle reading by repetition, determination of stadia constant, and running an azimuth traverse in which horizontal distances are determined by the stadia, and differences of elevation computed from the vertical angle. Note book and map. *Survey 4* consists of a compass survey of a closed field, location of boundaries and principal details, computation of area, and map. *Survey 5* consists of repetition traverse of a closed field, distances being measured by steel tape corrected for catenary, pull, and temperature. Determination of magnetic declination by observation on Polaris.

Pre-requisite: 2.

21—Highway Engineering. 2 hours. Professor LOVELL.

Road resistances—Design, construction, maintenance and repair, of Dirt, Gravel, Broken Stone and Miscellaneous Roads—Street Location—City pavements—Belgian and Granite Block, Brick, Asphalt and Wooden Block—Foundations—Grades—Drainage, Specifications. Reference and text-books: *Roads and Pavements*, Baker.

23—Theory of Railroad Surveying. 2 hours and 1 afternoon. Professor LOVELL and Mr. FINCH.

An abridged course, for students in Mining Engineering, covering the same subjects as are taken in Course 51-52.

Pre-requisite: 15.

25—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Survey 1 consists of running a line of levels for a water main or sewer, plotting profile, and computation of excavation. *Survey 2* consists of a topographic survey with plane table. Intersection, re-section, and traverse methods to be used, and map made. *Survey 3* consists of a topographic survey with transit and stadia; note-book and map. An optional course in photographic surveying may be offered in 1912. *Survey 4* consists of solar observations with transit and solar compass for the determination of the true meridian and magnetic declination. *Survey 5a*, City surveying, consists of the division of land into city blocks and subdivision into lots and the location of the street and lot lines; grade lines for streets and grades at street intersections; location and grade of sewers; including map, profile, and computation of excavation for street opening and sewer line. Relocation of lot lines and problems in surplus and deficiency, map showing property with record line and encroachments. Location of lines for buildings, bridge abutments, etc.

Pre-requisite: 15.

26—Surveying between the Third and Fourth Years. Hydrographic Survey. Field and office work. 2 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Survey made in conjunction with Geodetic Survey (total time 5 weeks, see page 70, Dept. of Astronomy), which furnishes main triangulation net for topographic and hydrographic control. Hydrographic survey consists of auxiliary triangulation, topography on shore by stadia, soundings, observations on outlet by current meter for river discharge, adjustment of angles, computation of triangulation system, also of river discharge, map and report.

Pre-requisite: 25.

27—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Same as C. E. 25 except *Survey 5a* is omitted and *Survey 5b* is added. *Survey 5b* consists of the location of a mining claim 1,500 feet long by 300 feet wide in conflict with existing claims, and the determination of the areas in conflict. The claim is located upon an outcrop of assumed dip and strike, in such a manner as to keep the center line close to the outcrop. Reports and maps.

Pre-requisite: 15.

28—Surveying between the Second and Third Years. Field work and office work. 3 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Railroad surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computation—Economic comparisons from construction and operating standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, calculations of earthworks, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 23, 27.

51-52—Theory of Railroad Surveying. 2 hours and 1 afternoon, first half-year, and 3 hours and 1 afternoon second half-year. Professor LOVELL and Mr. FINCH.

Simple, compound, and reversed curves—Transition curves—Switch work—Cross-section work—Earthwork computations—Cost of earthwork; cut and fill—Borrow—Waste and overhaul—Office work; Profile with mass curve showing proper distribution of excavation. Lectures and practical problems. Reference books: Searle's *Field Engineering* and Crandall's *Transition Curve and Earthwork.*

Pre-requisite: 15.

53-54—Elasticity and Resistance of the Materials of Engineering. 5 hours lectures and recitations first half. 6 hours first half-year of problem, design and laboratory work; 3 hours second half. Professors BURR and WILLIAMS, Mr. MACGREGOR and Mr. SAYRE.

Laws of elasticity in homogeneous materials—Coefficients of elasticity—Relations between stresses and strains—Common and exact theories of torsion and flexure—Elastic limits, working stresses, and ultimate resistances of wrought iron, cast iron, steel, alloys, timbers, building-stones, cement, concrete, and masonry—Reinforced concrete construction—Complete treatment of simple and continuous beams—The design and construction of iron, steel, and timber columns and beams, including the design and construction of plate girders—Shafts—Cables—Fatigue of materials—Specifications—Testing Laboratory—Discussion of properties of structural materials as shown by results of testing, by tension, compression, bending, and torsion—Report of tests. Reference and text-book: Burr's *Elasticity and Resistance of Materials.*

Pre-requisite: Mechanics 102.

55—Standard Methods of Water Analysis. 2 afternoons. Professor BLACK.

Physical and biological.

Pre-requisite: Zoology 7, Bacteriology 101, Civil Engineering 59.

57a—Statistics and Interpretation of Water Analyses. 20 lectures. Mr. G. C. WHIPPLE.

Collection, preparation and interpretation of vital statistics, for the identification of the sanitary condition of particular States, cities, or communities as affected by water and milk supplies, sewerage systems, industrial and economic conditions. Interpretation of complete water analyses.

57b—Drainage of Marshes and Lowlands. A course of 10 lectures. Professor BLACK.

Mosquitos, habits, breeding, methods of extermination. Malaria, yellow fever.

Pre-requisites for courses 57*a* and 57*b* are Zoology 7, Bacteriology 101, and Civil Engineering 59.

58—Masonry Structures. 3 hours and 1 afternoon with frequent conferences and continuous work in design. Cement and mortar testing in the cement-testing laboratory are required of all students. Professor WILLIAMS.

Pressure and abutting power of earth—Design and construction of retaining walls—Stability of masonry structures in general—Stability of towers and chimneys under wind pressure—Theory and design of arches with vertical and inclined loads—Theory and design of reservoir walls, earth and high masonry dams—Theory and Design of masonry domes—Cement, concrete, and masonry. Reference books: Ketchum's *Walls, Bins and Grain Elevators;* Morrison and Brodie's *High Masonry Dams,* and Baker's *Masonry and Foundations.*

Pre-requisite: Mechanics 101-102, Mineralogy 5.

59—Sanitary Engineering. 2 hours and 2 afternoons in January in Bacteriological Laboratory. Professor BLACK.

Treatment and disposal of sewage and refuse of manufacturing—Sedimentation by gravity and by chemical precipitation—Treatment of effluent by continuous and intermittent sand filtration—Septic tanks—Contact beds—Percolating or trickling filters—Fertilization—Intermittent application to soil with under-drainage—Disposal of sludge—Plants for sewage treatment—Theory and construction of sand filters—Pollution of potable water and its purification by continuous and intermittent sand filtration—Mechanical filtration—Copper sulphate, ozone and other treatments for special waters—Design of sand filter for water purification. Examinations of and reports on typical purification works. Biology and Bacteriology of drinking water. Text-books: *Filtration of Public Water Supplies,* Hazen; *Purification of Sewage,* Barwise.

Pre-requisite: Chemistry 82.

61—Analytical Theory of Trusses. 2 hours and 1 afternoon, with frequent conferences and problems in computations of stresses and preparation of stress sheets. Professor WILLIAMS.

The truss element—Simple cantilever and non-continuous trusses with parallel chords—Fixed and moving loads—Through and deck spans—Positions of any system of concentrated moving loads for greatest chord and web stresses when chords are both parallel and non-parallel—Combination of moments and graphic methods—Skew and irregular trusses—Applications to bridge and roof trusses—Braced arches and arched ribs. Reference and text-book: Burr and Falk's *Metallic Bridges.*

Pre-requisite: Mechanics 101-102.

62—Graphic Statics. 2 hours and 1 afternoon. Professor WILLIAMS.

For students in Civil Engineering—Equilibrium polygon, and polygonal frames for all systems of loads—Graphical representations of shears and moments for both non-continuous and continuous beams—Fixed and moving loads—Lines of influence—Applications to bridge and roof trusses. Reference and text-book: Burr and Falk's *Influence Lines.*

Pre-requisite: Mechanics 101-102.

64—Graphic Statics. 1 hour and 1 afternoon for mining engineers and metallurgist. Professor WILLIAMS.

An abridged course, covering the subjects taken in Course **62.**

Pre-requisite: Mechanics 101-102.

71—Surveying between the Third and Fourth Years. Field work and office work. 4 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Railroad Surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computations—Economic comparisons from construction and operation standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, earthwork quantities, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 51-52 and 25.

75—Hydraulics. 4 hours, with conferences and problems. Professor BLACK.

Flow of water through orifices—Time required for discharge of canal locks and similar volumes—Weir discharge and gauging by weirs—Gauging of water for systems of irrigation—Flow through and discharge of pipes—Design of pipe systems for city waterworks—The Venturi meter—Flow in and discharge of open canals and rivers—Gauging of streams by current meters, floats and other means—Backwater—Flow of compressible fluids. Text-book: Merriman's *Hydraulics.*

Pre-requisite: Mechanics 102, Math. 5.

76—Hydraulics. 2 hours. Professor BLACK.

For students in Mining Engineering—Course **75** abridged.

Pre-requisite: Mechanics 102, Math. 5.

77—Hydraulics. 2 hours. Professor BLACK.

For students in Electrical Engineering—Similar to Course **75,** but shorter. In addition it deals with the general considerations of rainfall, evaporation, percolation, run-off, net yield and storage; conduction of water from source to power-house, hydraulic losses and effective head on wheel; estimation of power. Text-book: Merriman's *Hydraulics.* Reference book: Turneaure and Russell's *Public Water Supplies.*

78—Hydraulics. 2 hours. Professor BLACK.

For students in Mechanical Engineering—Same as **76.**

85—Foundations. 2 hours and 1 afternoon, with frequent conferences and continuous work in design. Professor BURR.

Earth foundations—Foundations for buildings—Safe loads on masonry and foundation beds—Pile driving and pile foundations—Safe loads for piles—Protection and preservation of piles and timber—Sheet piling and coffer-dam methods—Pneumatic foundations and caisson work—Open dredging—Bridge piers of masonry and cylinders—Piers for deep foundations—Methods of working in quicksands—Tunneling. Reference books: Patton's *Foundations* and Baker's *Masonry and Foundations.*

Pre-requisite: 57-58, Geology 18.

87-88—The Design and Construction of Bridges, Roofs, and Buildings. 2 hours and 1 afternoon, with frequent conferences and continuous work in design. Professors BURR and WILLIAMS.

Railway and highway bridges—Pin and riveted connections—Single and multiple system of bracing—The design of details for bridges, roofs, and buildings—Floors for railway and highway bridges—The design and operation of draw-bridges, including engines, locking, lifting, and turning machinery—Cantilever structures—Wind roads and stresses—Single and double-track viaducts or trestles in iron, steel, and timber—Lateral and transverse systems of bracing—The design and construction of elevated railroads—The complete designs of railway structures, with estimates of cost—The erection of iron, steel, and timber structures, including the cost of erection. First half-year only for sanitary engineers. Reference and text-books: Burr and Falk's *Influence Lines;* Burr and Falk's *Metallic Bridges.*

Pre-requisite: 53-54, 61-62.

89-90—Railroad Engineering. 3 hours and 2 afternoons for conferences and design work. Professor LOVELL and Mr. FINCH.

Location, construction and operation—Train resistance, sources and probable value—Curvature and grades, their relation to velocity and maximum train-load—Effect of momentum—Reduction of grades at starting points—Balance of grades for unequal traffic—Study of annual reports—Analysis of operating expenses—Cost of operating, including maintenance, per train mile—Itemized statements of costs and percentage to total cost—Cost of extra distance, curvature, rise and fall, or of additional trains—Effect of roadbed on cost of running trains—Justifiable expenditure in construction to save one mile of distance, one degree of curvature, one foot of rise and fall, or to reduce ruling grade .1% per daily train per year—Pusher grade for one or more assistant engines—Economical use of pusher grades—Cost of excessive or limiting curvature—Value of additional traffic—Principles to follow in locating new lines—General policy of improvements in old lines—Principles in design and construction of railroad yards and terminals—Computations and detail drawings of turnouts, slip switches and ladder tracks—Development and present practice in block signalling and interlocking, with problems in design and estimates of cost of installation—Classification and cost of earthwork—Graduation, cross section in excavation and embankment, and protection of slopes—Ordinary and extraordinary methods of drainage—Water supply, its quality, storage, and delivery—Design of standard maintenance of way plans, including ballast—Track and track accessories—Organization—Management. Reference books: Wellington's *Railway Location—Elements of Railroad Engineering,* Raymond—*American Railway Transportation,* Johnson—*The Block System,* Adams—Camp's *Notes on Track*—Dewsnap's *Railway Organization and Working.*

Pre-requisite: 71.

94—The Design and Construction of Sewers, and River and Harbor Improvements. 2 hours lectures, recitations, problem and design work. Professor BLACK.

Sewerage and surface drainage of cities and towns—Separate and combined systems of sewers—Capacities of mains and branches—Catch basins—Manholes—Chimneys or ventilators—Flush tanks—Outfalls—Grades—Flow or discharge of sewers—Construction. River and Harbor Improvements—Jetty system of river improvements—Scouring action of currents—Erosion of river banks—Dams for improvement of river navigation—Breakwaters—Dykes—Groins—Mattress work—Docks—Harbor works—Iron piers—Estimates of cost. Text and reference books: *Separate System of Sewerage,* Staley and Pierson—*Sewer Design,* Ogden—*Flow of Water in Open Channels, Pipes, etc.,* Flynn.

Pre-requisite: 26, 59, 75.

96—Principles of Hygiene, Sanitary Science and Public Health. 3 hours.

Health and disease; the germ theory of disease; dust and its dangers; infection and contagion; drinking water, ice, milk, vegetables, shell-fish, etc., as vehicles of disease; flies, fleas and other disease carriers; general problems of public health and sanitation. Personal hygiene.

Pre-requisite: Civil Engineering 57*a* and 57*b*.

97—Water-Supply and Irrigation Engineering. 2 hours lectures, recitations, problem and design work. Professor BLACK.

Rainfall and storage—Flow of streams—influence of soils, elevation, geological character of water-shed—Methods of supply, gravitation, pumping from rivers or natural underground storage, flow from the latter, underground flow, wells—Reservoir construction—Distributing system. House supply and wastage. Irrigation of land—Amounts and periods of application—Construction of, and flow through, diversion and distributing canals. Text-book: *Public Water Supplies*, Turneaure & Russell.

Pre-requisite: **26, 59, 75.**

99-100—Graduation Thesis. A project or thesis on some civil engineering subject, approved by the head of the department, is required of every candidate for the degree of Civil Engineer.

Advanced Courses

The minor subjects in the department of Civil Engineering for the University degrees of Master of Arts and Doctor of Philosophy (those courses which fulfill the residence requirements) are the following:

153-154—Elasticity and Resistance of Minerals.

257-258—Elastic and Masonry Arches. Open to those who have taken **57-58.** Conferences, reading and design work, as required.

275-276—Hydraulics (75 with additional reading).

285-286—Foundations, including theory of earth pressure (**85** with additional reading).

287-288—Long Span Bridges. Open to those who have taken Civil Engineering **87-88.** Conferences, with reading and design work as required.

The major subjects for the same University degrees are the following:

259-260—Sanitary Engineering. Pre-requisite: Courses **59, 94, 98.**

277-278—Hydraulic Engineering, including the hydraulics of rivers and power plants and municipal water-works.

289-290—The Engineering of Structures, including long span sewage works, streets and other public works and their administration.

289-290—The Engineering of Structures, including long span bridges and deep foundations, with methods of building them, and advanced work in Elasticity and Resistance of materials.

Equipment

The drafting rooms and offices, situated on the fourth floor of the Engineering building, are equipped with a standard form of drafting table, and have a seating capacity for 175 students.

The collections of the department contain a complete set of models illustrating problems in projections and descriptive geometry, as well as the usual charts, blue prints, and models for use in the lecture and drafting rooms. A special feature of the collection is a full set of Olivier models illustrating the warped surfaces and problems in intersections and tangencies.

DRAFTING

1, 2—Drafting. 1 hour and 14 hours drafting. Professor MAYER, Mr. MILLER, Mr. HARRINGTON, and Mr. BEANS.

(*a*) Elements of mechanical drafting—Use of instruments; plane problems; free-hand lettering; dimensioning; (*b*) Projections—Orthographic projection; intersections; developments; problems in descriptive geometry; isometric projection; cabinet projection; (*c*) Machine drafting—Conventional signs for materials of construction; sketching of machine details. Working drawings; tracings; blue printing; (*d*) Topography—Conventional signs; hill shading; mapping.

3, 4—Descriptive Geometry. 3 hours. Professor MAYER, Mr. MILLER, and Mr. HARRINGTON.

Problems on point, line, and plane; classification of surfaces; tangent planes to single curved surfaces and surfaces of revolutions; intersections; developments; warped surfaces.

5, 6—Drafting. 6 hours. Professor MAYER and Mr. MILLER.

(*a*) Graphics—Shades and shadows; perspective; (*b*) Stone cutting—Buttress; wing-wall; arches.

Pre-requisite: Drafting 1-2, 3-4.

7, 8—Drafting. 6 hours. Professor MAYER, Mr. MILLER and Mr. HARRINGTON.

(*a*) Structural drafting—Standard rolled sections; conventional riveting signs; standard connections; methods of framing and detailing structural work; beams; columns; plate girder; roof trusses; bridge details; (*b*) Machine drafting—Working drawings; tracing and blue prints of machine details; boiler and engine-room layouts, etc.

Pre-requisite: Drafting 1-2, 3-4.

ECONOMICS

2—3 hours. Professors SEAGER and AGGER and Mr. ANDERSON.

Introduction to Economics. Lectures, reading and text-book discussion. In this course the fundamental principles of economics are studied with particular reference to their application to current economic and social problems in the United States, and with special regard to the needs of students in engineering. Third-year students in Electrical and fourth-year students in Mechanical Engineering.

ELECTRICAL ENGINEERING

2—Elements of the Dynamo. 2 hours. Professors ARENDT and MORECROFT, Messrs. HEHRE and MASON.

A general consideration of the principles and parts of Dynamo Electric Machinery. History, definition of dynamo and motor, reversibility of functions, magnetic field, magneto-motive-force, hysteresis, elementary dynamo, generation of e.m.f., collector rings and commutator. Parts of the dynamo; the magnetic circuit, materials and function. The armature core: materials, eddy currents, forms, construction. The armature winding: material, function, multiplication of electro-motive-force, types. The commutator: materials and construction. Brushes: function, materials and supports. Field frame: materials, forms, development of magnetic flux, windings, magnetic leakage. Armature reaction: cause of, back and cross ampere turns, brush shifting, sparking at brushes and remedies. Action of different types of dynamos, and typical forms. Text-book: Crocker's *Electric Lighting*, Vol. I.

Pre-requisite: Physics 3-4.

4—Electric Distribution. 2 hours. Professor ARENDT and Mr. HEHRE.

Principles and Methods of transmitting, distributing and controlling direct currents. Introductory, direct current series and parallel systems, feeders and mains, voltage regulation, networks, high tension d.c. systems.

Principles of alternating currents, self and mutual inductance, capacity, impedance, effective values of current and voltage, phase angle and power factor. Text-book: Crocker's *Electric Lighting*, Vol. II.

For E.M., C.E., M.E., Met.E., Chem.E. and San.E. students.

Pre-requisite: Phys. 5 and E. E. 2.

52—Design of Direct-Current Machinery. 2 hours and 1 afternoon. Professor ARENDT.

Application of electrical and mechanical theory to the design and calculation of D. C. machinery with a complete and original design of a dynamo or motor in accordance with specifications, requiring all calculations and working drawings. Text-book: Thompson's *Design of Dynamos.*

Pre-requisite: Phys. 5 and E. E. 2. Parallel course: E. E. 173-174.

54—Design of Alternating-Current Machinery. 2 hours and 1 afternoon. Professor SLICHTER.

The application of alternating current theory and practical data to the calculation and design of alternators, transformers, induction motors and other alternating current apparatus. Reference books: Arnold's *Wechselstromtechnik;* Thompson's *Dynamo Electric Machinery,* Vol. II, and McAllister's *Alternating Current Motors.*

Pre-requisite: E. E. 52 and Mechanics 108. Parallel course: Mechanics 110 and E. E. 175-176.

72—Direct-Current Laboratory. 1 hour and 1 afternoon. Mr. HEHRE and Mr. MASON.

Short Course for students in Mining, Metallurgical, Civil, Chemical Engineering and Chemistry. The experiments cover the following: Fall of Potential, Resistance determinations, Study of various types of D. C. generators, their connections and characteristics of operation. Working of generators in parallel. Study of various types of motors, their connections, characteristics of operation and determination of commercial efficiency by brake tests. The results of these experiments are handed in as reports which are returned promptly to the students, with comments and corrections. Text-book: Sever's *Electrical Engineering Experiments, etc.*

Pre-requisite: Phys. 5, 43 or 44 and E. E. 2.

73—Direct-Current Laboratory Work. 1 afternoon. Mr. HEHRE.

Short course for students in Mechanical Engineering. Same as 72.

Pre-requisite: Phys. 5, 43 or 44 and E. E. 2 with parallel course E. E. 101.

75—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Assistants.

Short course for Mining and Mechanical Engineering students. The experiments cover the following: Study of Elementary phenomena of alternating current circuits, with determination of inductance, capacity, impedance, true watts, apparent watts and power factor. Study of an Alternator, its operation, characteristic curves and wave form. Transformers: Their operation and commercial efficiency. Induction motors: Characteristics and efficiency by brake tests. Synchronous motors, their operation under various conditions and characteristic curves. Rotary converters, operation under various conditions of load and power factor (direct and inverted). Alternators in parallel, division of load and conditions for maximum economy. The student is required to prepare a report upon each experiment which is promptly corrected and returned to him for his instruction. Text-book: Townsend's *Short Course in Alternating Current Testing.*

Pre-requisite: E. E. 72 or 73 and 4 or 104.

76—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Assistants.

Short course for Civil Engineers. Same as 75.

Pre-requisite: E. E. 4 and 72 or 73.

98—Thesis. Original investigation of and report on some problem of Electrical Engineering, approved of by the head of the department. Optional.

101—Generator and Motor Practice. 3 hours. Professor SLICHTER and Mr. HEHRE.

A course of lectures parallel to and descriptive of D. C. laboratory work. Short circuits and protective devices. Instruments: construction and use. Armature: e. m. f. current resistance of, voltage drop in, windings and connections. Commutator: function, construction, heating, sparking, collecting brushes and holders. Magnetic circuit: calculation of flux and field windings. Heating of field and armature. Characteristics of the various types of generators and methods of regulation. Motors, theory of action and types. Methods of control and speed regulation. Losses and determination of efficiency by brake, stray power and pumping back methods. Text-books: Crocker's *Electric Lighting,* Vol. I, and Sever-Townsend's *Laboratory and Factory Tests in Electrical Engineering.*

Pre-requisite: Phys. 5 and E. E. 2.

103—Electric Motors. 3 hours. Professor ARENDT.

(For E.E.) Electric motors, their action, control and application. Introductory. Classification of work requirements. Shunt Motors: Characteristics, predetermination of action, and efficiency, methods of speed control and regulation, rheostatic, field weakening, multiple voltage, double armature and teaser system. Series Motors: Connections, predetermination of characteristics and efficiency, control: rheostatic, field weakening, double armature and series parallel. Compound motor, characteristics and methods of control. Alternating current motors introductory. Commutator A. C. motors, series and repulsion types, characteristics and control. Synchronous Motors, characteristics and control. Induction Motors, single and polyphase, characteristics, methods of starting, speed control and regulation. Electric Drive, advantages of and application to machine tools, cranes, elevators, presses, pumps, fans, wood working and mill work. Text-book and Electric Motors by Crocker and Arendt.

Pre-requisite: E. E. 104, 173 and 174. Parallel course: E. E. 175-176.

103A—Electric Motors. 2 hours. Professor ARENDT.

Electric Motors, their action, control and application. 103 abridged for Mechanical Engineering Students.

Pre-requisite: E. E. 4 and 73. Parallel course: E. E. 75.

104—Electric Distribution. 3 hours. Professor SLICHTER.

Principles and methods of transmitting, distributing and controlling direct and alternating currents. Introductory, Physical properties of conductors, direct-current series and parallel systems of distribution, feeders and mains, voltage regulation, three-wire systems, high voltage direct-current systems, network systems.

Principles of alternating currents, study of wave shapes, inductance, capacity, phase angle, effective values of electromotive force and current, power factor, resonance, simple circuits, parallel circuits, line inductance and distributed capacity, calculation of single phase circuits. Text-book: Crocker's *Electric Lighting,* Vol. II.

Pre-requisite: Phys. 5 and E. E. 2.

105—Alternating-Current Engineering. 3 hours. Professor SLICHTER.

Electric power systems, including translating, controlling and transmitting equipments. Constant potential and constant current transformers, principles, efficiency, regulation and protection. Polyphase systems of generation, two phase and three phase, economy of generators, of transmission, and conversion from one system to another. Calculation of alternating current transmission lines, regulation of voltage and power factor of systems. Switch-boards, materials, apparatus used upon, location and types. Line construction and protection, pole lines, cable and conduit systems. Text-book: Crocker's *Electric Lighting,* Vols. I and II.

Pre-requisite: E. E. 101 and 104. Parallel course: E. E. 175-176.

105A—Alternating-Current Engineering. 2 hours. Professor SLICHTER.

105 abridged for Mechanical Engineering students.

Pre-requisite: E. E. 4 and 101. Parallel course: E. E. 75.

106—Electric Plants. 2 hours. Professors SLICHTER and ARENDT and special lecturers.

Management of electric plants and industrial enterprises. Electric illumination, methods of charging for electric power, operating expenses, sources of income, organization and administration of corporations, reports, specifications, contracts, insurance regulations, patents and statistics.

Pre-requisite: E. E. 104.

107-108—Plant Inspection. 3 hours. Professors SLICHTER and ARENDT.

Pre-requisite: E. E. 104, 173-174. Parallel course: E. E. 105 and 106.

109-110—Telegraphy and Telephony. 1 hour. Professor ARENDT.

The principal methods and instruments employed in telegraphy, telephony and electric signalling. Telegraphy: Historical review, Morse systems, relays and sounders, earth circuits, station equipments, repeaters, differential and polarized relays, duplex systems, quadruplex systems, telegraphy from moving bodies, recording systems, submarine cables and telegraph circuits. Wireless telegraphy: Generation of electrical waves, simple transmitting and receiving apparatus. Telephony: Historical review, Bell's work, the magneto-telephone, the microphone and carbon transmitters, use of induction coils, call methods, series and parallel circuits, subscriber's equipment, line disturbances, common battery systems, subscriber's and exchange equipment, party lines, automatic systems, combined telegraphy and telephony. Text-books: Mayer's *American Telegraph Practice* and Miller's *American Telephone Practice.*

Pre-requisite: E. E. 104.

112—Electric Railway. 2 hours. Professor SLICHTER.

Special instruction in calculation, installation and operation of electric railway systems. Historical review and early development. Train resistances due to tracks and bearing surfaces, curves, grades, and air. Acceleration and breaking. Speed time curves. Motors for railway work. Controllers. Distribution systems, track construction, bonding and electrolysis. Trucks, wheels and car bodies. Conduit, storage battery and third rail systems. Electric locomotives and multiple unit control. Testing railway equipments. Financial considerations.

Pre-requisite: E. E. 104 and 173-174.

112A—Electric Railway. 2 hours. Professor SLICHTER.

112 abridged for Civil Engineers.

Pre-requisite: E. E. 4 and 72.

173-174—Direct-Current Laboratory. 6 hours (2 afternoons). Mr. HEHRE.

1. Practice in the accurate use of voltmeters and ammeters for the measurement of electromotive force and current. Determination of resistance of the electrical circuits of electrical machinery by "drop," comparison and direct deflection methods. Use of Wheatstone bridge for determination of high resistance. 2. Generators: Preliminary study to bring out relations between speed, field strength and voltage. Operation of shunt, series and compound-wound generators with determination of characteristic action of each type. Distribution of potential around commutator and distorting effects due to armature reactions. Heat runs to determine load capacity and efficiency determinations by means of stray power and "pumping back" tests. 3. Motors: Function and operation of starting boxes, study of motors, existence and measurement of c.e.m.f., operation of shunt, series, compound and differentially wound motors, determination of speed-load curves of each type. Efficiency tests by brake and stray-power methods. 4. Operation of shunt and compound-wound generators in parallel, methods of connecting, distribution of load, effects of individual differences, etc. 5. Constant Current Dynamos: Comparison of characteristics of constant potential and constant current circuits, methods of governing constant current machines, action under variable loads, control of series circuits, regulation of arc lamps. Text-book: Sever and Townsend's *Factory and Laboratory Tests in Electrical Engineering.*

Pre-requisite: Phys. 5, 43 or 44 and E. E. 2. Parallel course: E. E. 101.

175-176—Alternating-Current Laboratory. 1 hour and 6 hours laboratory practice (one whole day) first term, 1 hour and 6 hours laboratory practice (2 afternoons) second term. Professor MORECROFT with Assistants.

1. Alternating current circuits: determination of inductance, capacity, impedance, phase relations, true and apparent watts and power factor. 2. Alternators: operation at different power factors, magnetization curves, determination of losses and synchronous impedance, field compounding, etc. 3. Synchronous Motors: Methods of synchronizing, efficiency, action under varying conditions of load and field current. 4. Rotary converters: Methods of starting, operation direct and inverted, compounding, determination of voltage ratios and calculation of efficiency. 5. Alternators in Parallel: division of load, cross currents and adjustment of excitation for maximum economy. 6. Transformers: operation, determination of losses, regulation, heating and efficiency. Use as induction regulators and phase changers. 7. Wave Forms: determination of wave shapes and phase relations of electromotive-force and current in relative and non-relative circuits as well as in the primary and secondary circuits of transformers by instantaneous contact and oscillograph methods. 8. Resonance: by means of inductance and capacity in series, by inductance and leading current produced by synchronous motors, with application to transmission lines and rotary converter regulation. 9. Induction Motors: methods of starting, characteristic curves, determination of losses and efficiency by brake tests, application of circle diagram and use as frequency changer. 10. Induction Generator: operation and determination of the external characteristic. Text-book: Sever and Townsend's *Factory and Laboratory Tests in Electrical Engineering.*

Pre-requisite: E. E. 104 and 173-174. Parallel courses: E. E. 103 and 105; Mech. 109 and 110.

177—Instrument Laboratory. 1 hour and 2 afternoons. Mr. MASON.

1. Calibration of ammeters by comparison with laboratory standards. Kelvin balances, Siemens' dynamometers, and potentiometers. 2. Calibration of voltmeters. 3. Calibration, adjustment and determination of constants of A. C. and D. C. watt-hour meters, by various methods. 4. Determination of resistances: by Wheatstone bridge and potentiometer methods. 5. Measurements of Inductance

and capacity. *a.* By comparison with standards using A. C. bridge. *b.* By absolute method, including determination of constants of ballistic galvanometer. 6. Magnetic measurements. Determination of coefficient of magnetic leakage of generator or motor. Determination of the permeability of samples of iron and steel. *a.* By Hopkinson's method. *b.* By Ewing double bridge method. *c.* A. C. voltmeter method. *d.* Direct reading voltmeter method. Determination of Hysteresis by Hopkinson's Double bridge. Voltmeter and Ewing tester methods. 7. Storage Battery Testing. Determination of normal rate of discharge, capacity and efficiency at normal rates, capacity at various rates. Constant current and constant potential methods of charging, weight efficiency and losses on standing. 8. Photometry. *a.* Proving gas meters and determination of candle power of gas against standard candles. *b.* Candle power incandescent lamps using standard candle. *c.* Distribution of light from an incandescent lamp, using secondary standard. *d.* Determination of mean spherical and mean hemispherical candle power of an incandescent lamp. *e.* Relations between voltage, candle power, efficiency and life of incandescent lamps. Arc lamp photometry. 9. Cable Testing. *a.* To determine insulation resistance; induction and capacity. *b.* To determine location of faults. Text-book: Sever and Townsend's *Factory and Laboratory Tests in Electrical Engineering.*

Pre-requisite: E. E. 173-174.

Graduate Courses

101, 104 and 173-174—Dynamo and Motor Practice, Electrical Distribution and D. C. Electrical Laboratory. 3 hours and 6 hours laboratory.

Pre-requisite: Phys. 5, 43 or 44 and E. E. 2.

175-176—Alternating-Current Laboratory. With Mechanics 109 and 110. 5 hours first half-year, 4 hours second half-year and 2 afternoons.

Pre-requisite: E. E. 104, 173-174, and Mechanics 108.

103, 105, 106, 175-176 and 177—Electric Motors, Alternating Current Engineering and Electric Plants, and Electrical Laboratory. 8 hours, 4 afternoons first half-year; 3 hours, 2 afternoons second half-year.

Pre-requisite: E. E. 104, 173-174.

GEOLOGY

4—Petrography. 2 afternoons two months of the second half third year. Professor Berkey.

A short course in the microscopic study of rocks.

Pre-requisite: Mineralogy 6.

5-6—General Geology. 3 hours lectures, second year. Professors Kemp and Berkey.

First half-year physical geology, with practical work in the rock collections under the lithological part of the subject; second half-year, stratigraphical and historical geology, involving laboratory work with type fossils and collections illustrating the geology of the United States. Text-books: Kemp's *Hand-book of Rocks;* Scott's *Introduction to Geology.*

Pre-requisite: Mineralogy 1.

16—Index Fossils. 1 hour lecture, 8 hours laboratory, second term. Professor GRABAU and Mr. ——

A study of the invertebrate fossils characteristic of the various geologic horizons of North America.

18—General Geology. Professor BERKEY.

A general discussion of dynamical, structural and historical geology, with practical work in the rock collections and assigned field work on Saturdays during the last six weeks. Special course during the second half-year for students in Civil Engineering only.

19—Physiographic and Applied Geology. 3 hours lectures and laboratory by appointment, first term. Professor BERKEY.

A study of topographic and structural features and their representation on maps; application of geologic principles to engineering enterprises; water supply; illustrative problems. Open to students who have completed a course in general geology.

20—Rocks and Soils. 2 hours lectures and recitations, second term. Professor BERKEY.

A study of the residuary products from rock decay; types of soils; soil classification and mapping. Open to students who have completed a course in general geology.

51—Principles of Geology. 2 lectures per week. Professors GRABAU and BERKEY.

Principles of the formation of sedimentary deposits, involving a discussion of marine and continental sedimentation, the criteria by which various sediments can be recognized, methods of preservation of organic remains, and the principles of geographic and geologic distribution of organisms. Principles of correlation. Text-book: Grabau's *Principles of Stratigraphy.*

52—Principles of Geology. 2 lectures per week, second term. Professors GRABAU and BERKEY.

A discussion of secondary structural features; principles of formation of folds, faults, etc. Vulcanism, metamorphism, secondary mineralization.

105-106—Economic Geology. 3 hours lectures and one elective conference, third year. Professor KEMP.

First half-year, discussion of the general features and formation of ore bodies, followed by a description of the deposits of the ores of iron, copper, lead, zinc, silver, gold, and the lesser metals, with especial reference to North America; second half-year, a description of the distribution and occurrences of coal, petroleum, natural gas, asphalt, building-stone, water supply, salines, and minor minerals. Text-book: Kemp's *Ore Deposits of the United States and Canada,* and lecture notes privately printed.

Pre-requisite: Geology 5-6.

107-108—Invertebrate Palæontology. 2 hours lecture and 4 hours or more laboratory. Professor GRABAU and Mr. ——

First part of the course deals with the principles of palæontology; methods of study of the ontogeny of hard parts of animals, and the laws of morphogenesis. This is followed by a consideration of the classes of invertebrates important from a palæontologist's point of view, emphasis being laid on the features which show genetic relationship. Special attention is given to groups whose evolution has been worked out. Text-book: Zittel-Eastman, *Text-book of Palæontology,* Vol. I.

110—Geological Examinations and Surveys. 2 hours, second half fourth year. Professor KEMP.

A discussion of the methods of systematically recording and interpreting geological phenomena, with illustrations drawn from experience in mining and other branches of engineering; and of the organization and scope of geological surveys on a larger scale. This is followed by a sketch of the history and results of state and national geological surveys in this and other countries; and of other sources of detailed information regarding local geology.

Pre-requisite: Geology 105-106.

112—Field Geology.

A summer course of a week or ten days near New York for students in the course of Mining Engineering. Graduate students in the department may join the party. Instruction is given in the field in observing, recording, and interpreting geological phenomena and in the preparation of maps and sections. A written report is required.

201-202—Petrology. 2 hours lectures and 4 hours laboratory, fourth year. Professors KEMP and BERKEY.

A discussion of the origin, microscopic structure, and mineralogical composition of the crystalline rocks, and of metamorphism.

Pre-requisite: Mineralogy 6.

LAW

Business Law. 3 hours. Professor KIRCHWEY and Mr. WHITAKER.

A discussion of the elementary rules of law governing business transactions, including real property, contracts, agency, commercial paper, sales, suretyship, bailments, torts, partnership, corporations. The rules of law are developed and illustrated by examples taken from the reports, and dealing with situations such as engineers have in fact met and are apt to meet in the practice of their profession.

MATHEMATICS

1—Algebra. 2 hours. Professors FITE, HAWKES and GROVE, Mr. SICELOFF, Dr. REDDICK and Dr. LENNES.

Includes such topics as determinants, complex numbers, the theory of equations and partial fractions. First term.

Pre-requisite: Entrance Mathematics.

2—Algebra. Professor HAWKES and Mr. ——

Equivalent of 1. Second term.

3—Analytical Geometry. 3 hours. Professors FITE and HAWKES, Mr. SICELOFF and Dr. LENNES.

Introduction to algebraic geometry, dealing with such topics as co-ordinate systems, transformations, loci and their equations, the straight line, circle, parabola, ellipse, hyperbola, the geometric interpretation of the general equation of second degree, and the elements of three-dimensional geometry. First term.

Pre-requisite: Entrance Mathematics.

4—Analytical Geometry. Mr. —— and Dr. REDDICK.

Equivalent of 3. Second term.

64—Calculus. 5 hours. Professors MITCHELL and FITE, Mr. SICELOFF, Dr. REDDICK and Dr. LENNES.

An introduction constituting with **65** (see below) one course in the calculus. Differentiation of algebraic and transcendental functions, with applications to geometry, maxima and minima and mechanics. Second term.

Pre-requisite: **3** (or **4**).

65—Calculus. 5 hours. Professors KEYSER, FISKE, MACLAY, MITCHELL, FITE, Dr. GROVE and Dr. REDDICK.

Continuation of **64**. Further study of the differential calculus; the principles of the integral calculus; applications to geometry, physics and mechanics. First term of second year.

Pre-requisite: **3** (or **4**), and **64** (or **67**).

67—Calculus. Professor GROVE and Dr. LENNES.

Equivalent of **64**. First term.

68—Calculus. Professor GROVE and Dr. LENNES.

Equivalent of **65**. Second term.

MECHANICAL ENGINEERING

11-12—Steam Power Machinery. 3 hours, 1 afternoon in the second half year. Professors LUCKE, PARR and Mr. GUNN.

Functions, Forms and Principles of Operation of the Typical Steam power Plant Units, Auxiliaries and Connecting Elements—Methods of receiving, storing and firing coal, coal handling machinery, grates, stokers and furnaces for the combustion of coal; smokeless combustion and smoke ordinances; flow of gases through boilers, flues, dampers and the generation of necessary draft by chimneys, fans and steam jets. The construction and operation of boilers, boiler settings and foundations. Methods and apparatus for feeding water to boilers, necessary boiler attachments and trimmings. Flow of steam from boilers to engines and the grouping of engines and boilers, piping, valves, fittings and pipe covering. The heating of boiler feed water in feed water heaters and economizers. Purification of boiler feed water and effects of impure water on the boiler. Boiler strength tests and inspection laws. Boiler explosions. Steam pipe condensation and drainage. Steam traps, separators, steam superheating and superheaters. Condensing operation of steam engines by jet, surface, ejector and barometric condensers. Necessity for and types of circulating, hot-well and dry vacuum pumps and cooling towers. Typical steam engines and the variations in form and character of their important parts. Engine valves of simple and complete form, relation between construction of engine and valve gear to its economy. Special valve gears for high economy, for reserving and for power control. Regulation of engines and engine governors. Relation between engine construction, foundations, vibrations and balancing. Steam turbines. Typical steam plant arrangements for various special and standard conditions.

Pre-requisite course: Physics **3**.

13-14—Steam Power Machinery. 3 hours. Professor LUCKE and Mr. GUNN.

Short course adapted from M. E. **11-12**. Second year Civil and Electrical; Third year Metallurgical, Chemical, and Mining Engineering; Fourth year Chemical.

Pre-requisite course: Physics **3**.

17-18—Engineering Thermodynamics. 2 hours. Professor LUCKE and Mr. GUNN.

Laws of Heat Generation by Combustion, Heat Transfer and Transformation into Work—Relation between temperatures and quantities of heat. Units of heat. Effect of heat on solids, liquids, gases and vapors. Laws of heat transfer. Laws of surface evaporation, ebullition and condensation. Properties of saturated and superheated vapors. Combustion of fuels, calorific power, quantities of air for combustion. Temperature of combustion. Boiler efficiency and conditions affecting. Principles of chimney draft. Laws of expansion and compression of gases. Work and heat diagrams to pressure volumes and temperature entropy co-ordinates. Air and wet vapor compression. Expansion of steam by hypothetic, adiabatic and saturation laws and application to steam engine efficiency. Missing water in steam engines. Influence of cylinder condensation, re-evaporation, steam jackets, initial superheat, compounding and reheating on steam engine efficiency. Relation of boiler and engine performance. Free expansion laws and application to injector and steam turbine nozzles. Heat transformation by perfect gases. Hot air, gas and oil engine efficiency. Mechanical refrigeration. Effects of evaporation of ammonia and carbonic acid and expansion of air. Heat balances and combined efficiency of complex systems.

Third year Mechanical, Electrical, and Civil Engineering; Third year Mining Engineering for first term.

Pre-requisite courses: Mechanics **102**; M. E. **11-12** or **13-14**.

19-20—Engine Design. 3 hours and 3 afternoons. Professors RAUTENSTRAUCH and THOMAS.

Advanced Machine Design Based on the Thermal and Mechanical Problems Involved in the Design of a Steam Engine for Power, Economy and Regulation—Determination of ideal indicator card, probable M.E.P., piston speed, R.P.M., and displacement for required power, selection of single or multiple expansion construction from economy requirements, limits of clearance, cutoff, release, compression and admission for type of valve gear selected. Stresses due to steam and inertia in the principal parts. Forms and proportions of the parts determined by intensity, distribution and nature of the stresses, properties of the materials and conditions affecting maintenance. Determination of proportions of engine parts. Design of fly-wheels for limiting variation in velocity and analysis of resulting angular variation. Balancing the engine. Valve gears and governors, determination of the proportions of the valve for predetermined steam distribution, analysis of valve movements and moving gear. Graphic representation of the simultaneous events of valve opening, steam velocities and piston velocities. Analysis for the effect of the angularity of the rod. Equalizing the events of the valve. Analysis of the characteristics of the shifting eccentrics and the resultant variations in the valve events. Layout of the Corliss valve gear with single and double eccentric, and proportions of the mechanism. Steam engine governors, flyball and shaft governors, limits of movement, valve gear resistance. Proportions of the governor.

Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. **39, 40, 11, 12, 17-18.**

22—Gas Power Machinery. 4 hours and 1 afternoon. Professors LUCKE, PARR and Mr. GUNN.

Theoretical and Practical Consideration Affecting the Generation of Power by Gas Engines, Including Oil Vaporization, Coal Gasification and the Design of the Machinery—Efficiency, M.E.P., displacement per minute per I.H.P. for reference diagrams. Limitations of external and internal heating. Methods of explosive and non-explosive internal heating. Properties of explosive gas mixtures, air necessary, calorific power per cu. ft. of mixture; temperature of combustion, heat suppression, efficiency of combustion, pressure and volume effects, limitations of proportions, temperature of ignition, rate of propagation, the explosive wave. Critical examination of modern gas engine forms and functions of parts; means for mixing and proportioning, pressure regulators, ignition; governors, effects on the engine and mechanism; starting equipment;exhaust piping and muffling; effects of back pressure in the engine; cooling; preignition, effect of cooling on economy. Large blast furnace practice, methods of gas cleaning; blast furnace gas, quality. Large engine construction, and forms of parts. Producer gas practice; standard producer for anthracite and bituminous coal, characteristics; gas, variation in quality, effects on the engine; methods of blasting producers, auxiliary steam supply and steam consumption; efficiency and rate of combustion in producer; scrubbers and tar

extractors. Carburetors and vaporizers for liquid fuel; petroleum distillates, crude oil and denatured alcohol, vapor tension curves for liquid fuels. Characteristics of modern forms of gasoline and oil engines, gas power plant arrangements, producer engines, their efficiency, coal consumption and comparison with steam plants.

Complete analysis of the rating, efficiency, regulation, forces acting in and strength of parts of a modern gas engine. Probable indicator card, inertia of reciprocating parts, wrist pin and turning effort diagram. Dimensions of all parts.

Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. **19, 33.**

25—Steam Power. 3 hours and 2 afternoons. Professor LUCKE and Mr. GUNN.

Relation Between the Cost of Power and Thermal Efficiency of the Plant. Commercial Value of Refinements—Determination of engine and boiler ratings and corresponding efficiencies and probable coal and water consumption for plant on given load curve. Essential relation between processes and dimensions of the steam plant. Steam plant refinements for raising efficiency of part or complete plant and relations between dimensions and effect. Use of unit costs of apparatus in estimating, examination of cost sheets to determine prime unit of cost. Cost of power. Fixed and operating charges, ratio of each individual item to total and effect of labor and fuel rates, load factor and refinements on the fractional part. Value of refinements of design on basis of capitalized annual saving by comparing the cost of waste and the cost of its elimination, including all charges. Specifications and contracts; standard and special methods and forms for defining purchaser's requirements and builder's proposals, contracts, methods of power plant erection. Designing and erecting office organization and field systems.

The work consists in laying out a simple power plant for assigned units in the drafting room or the detailing of existing general plant drawings, preparation of the bill of materials, estimating the first cost, fixed charges, probable coal, water, labor and supply cost for an assumed load curve and total power cost. The plants so designed or detailed are exchanged by students and redesigned for an increase of 100 per cent. peak and 50 per cent. mean daily load and for the maximum power cost reduction by the use of plant refinements and auxiliaries when it can be shown that additions and alterations will pay. Specifications are written for the alteration and proposals submitted.

Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. **96S.**

31-32—Standard Tests and Research Methods. 1 hour and 1 afternoon. Mr. THURSTON.

Laboratory methods for the determination of experimental data. Derivation of physical laws from experimental results—Comparison of actual performance of machines with computed prediction and evaluation of unknown elements. Methods of approach for the solution of practical problems by experiment and computation. The work is illustrated by problems on the flow of liquids, gases and vapors, combustion, transfer of heat, steam generation and changes of state, transformation of energy, power generation and transmission, energy losses, thermal, hydraulic and mechanical. For each problem a preliminary report is submitted before the test, involving the analysis of the problem, the attempted prediction and the required test log, based on class-room explanations; this is incorporated with the tests results and an interpretation of differences between these and the prediction, including judgment of errors, to constitute the final report. The apparatus for this course includes: Pressure gauges, manometers, thermometers, pyrometers, indicators, tachometers, planimeters, barometers, weirs, channels, nozzles and orifices for water, steam and air, Pitot and Venturi tubes, steam, gas and water piping and meters, dynamometers, power scales, viscosimeters, flue gas apparatus, steam traps, hydraulic ram, steam injectors, air pump, hot air engine, duplex steam pumps, Pelton wheel, centrifugal pump, simple steam engine. Texts: *Experimental Engineering*—Carpenter, *Experimental Engineering*—Pullen, *Lecture Notes.*

Third year Mechanical Engineering.

Pre-requisite courses: M. E. **11-12.** Courses which are parallel to it: M. E. **17-18** and Mechanics **105.**

33—Standard Tests and Research Methods (Continuation of Course **31-32**). 2 hours and 1 afternoon. Professor PARR and Mr. THURSTON.

The work of this course is the same in nature as **31-32**, but the problems involve more difficult computations and more skilful manipulation of the apparatus. These problems are principally concerned with energy transformation, necessary and

accidental losses and the determination of the conditions affecting performance of compound and triple expansion steam engines and pumps, operating condensing and non-condensing, with and without receivers, with and without reheaters. Hydraulic motors, one, two and three stage air compressors, with and without intercoolers, feed water heaters, fans, steam boilers, ammonia refrigerating machines, steam superheaters and condensers. Attention is also given to the commercial tests standardized by the Engineering Societies.

Fourth year Mechanical Engineering.

Pre-requisite courses: M. E. **31-32**; M. E. **96S**; M. E. **17-18.**

35-36—Kinematics of Machinery. 1 afternoon. Professor THOMAS.

Determination of Paths of Motion, Velocity, Acceleration and Kinetic Forces of the Moving Parts of Machines with the Resulting Reaction Forces of the Frame—Relative motions of machine parts and the determination of the rates of motion. Determination of space, velocity and acceleration diagrams with application to the steam engine, shaper and other standard mechanisms. Construction and use of diagrams for the determination of inertia forces and their distribution in each element of a machine. The layout of motions to specifications. Design of cams with special reference to the rate of change of velocity of the moving parts and the resultant inertia forces, resistances to motion and the continuous contact of cam and follower. Analysis of link work, relative motions, inversions, adaptability to the accomplishment of specific kinds and limits of motion. Eccentrics and links for the transformation of kinds of motion; ratchet motion; running ratchets. Clutch and coupling mechanisms, connecting shafts in parallel and at an angle. Modification to permit of non-alignment. Toothed gearings. Justification of the cycloidal and involute curves in their application to gear teeth. The layout of tooth forms and the determination of the velocity ratios. Layout of bevel gear tooth forms by Tredgold's method. Approximate methods and practical rules for the layout of gear teeth. Determination of paths of contact, obliquity of motion, length of teeth, interferences in involute gearing. Determination of the necessary conditions for interchangeability in sets of cycloidal and involute gears and comparison of the system. Friction gears. Kinematics of belt drive. Open and crossed belts. Layout of belt drives and rope drives, sprocket wheels and chain drives, speed changing devices using wrapping connections. Text: *Kinematics of Machinery*—Durley.

Second year Mechanical and third year Electrical Engineering.

Pre-requisite courses are Math. **3-4** and M. E. **59.**

37—Machine Design. 1 hour, 2 afternoons, first half-year. Professor RAUTENSTRAUCH.

Adapted from M.E. **39-40.**

Fourth year Chemical Engineers.

Pre-requisite: Drafting **7.**

39-40—Machine Design. 1 hour, 2 afternoons, first half-year, 2 hours, 2 afternoons, second term. Professor RAUTENSTRAUCH.

Analysis of stress in machine parts of standard form under varying conditions of service and the proportions of the machine elements to safely resist the resulting stresses—Application of the principles of Kinematics, Resistance of Materials, Design of Machine Elements, Shop and Foundry Methods to the design and analysis of complete machines. Examination of machines to determine the nature and distribution of the forces acting on and the resulting stresses and strains in each element due to kinetic and structural conditions. Selection of working stresses for machine parts subject to steady, repeated and reversed stresses. Selection of materials for machine parts based on their adaptability to the service and to the shop processes by which the part must be made. Determination of the proportions of machine parts subjected to tension, compression, and shear; bending and torsion; combined bending and tension, bending and torsion, torsion and compression, buckling action, and stresses due to eccentric loading and complex supports. Illustrated in the design of crank shafts, machine frames, housings and connecting rods. Gear wheels, pulleys, flywheels, springs, riveted joints, thin and thick cylinders, braces and stays, flat plate members, pressure joints, screws, belting, rope and chain drives for power transmission. Bearing surfaces, flat, cylindrical, pivot, ball, roller, thrust. Application of theory of elasticity to the more complicated elements. Grouping of machine elements into machines for functional operation, erection, adjustment, maintenance and repair and modifications demanded by facilities for manufacture. Design of machines to specification, with particular reference to modern requirements. Text: Spooner's *Machine Design.*

Third year Mechanical Engineers.

Pre-requisite courses: M. E. **36.** Must parallel C. E. **53.**

41—Machine Design. 1 hour and 1 afternoon. Professor THOMAS.

A short course adapted from M. E. **39-40**.

Fourth year Civil and third year Electrical Engineering.

Pre-requisite courses: C. E. **53** for C. E. Must parallel C. E. **53** for E. E.

46—Water Power Machinery. 3 hours. Mr. HERRICK.

Principles of Design and Economy of Operation of Turbine Wheels and Water Power Plants—Action of water on curved vanes, forces developed and effect of impact, work done; centrifugal action. Theory of reaction turbines. Vane form and arrangement; total work done for axial, radial and mixed flow wheels; dependence of velocity of flow on speed of rotation; losses of energy due to friction in guide passages, wheel buckets and sluice, shock, leakage, residual velocity. Design of reaction turbines; relation between pressure and velocity of flow; methods of determining passage areas; radii of wheels, width and depth of buckets, number and thickness of vanes. Axial turbines, characteristics, forms and dimensions. Impulse turbines; essential principles and theory, advantages, ventilation of bucket, velocity of flow, available energy, efficiency. Axial impulse turbines, characteristics, forms and dimensions. Centrifugal action in axial flow, reaction and impulse turbines. Radial impulse turbines, inward and outward flow; forms, characteristics and dimensions. Descriptions of and experiments with turbines of various types. Existing water power plants. Modern governors for turbines; ideal action of direct acting governor and disturbing influences; essential principle of indirect acting governor; factors affecting regulation.

Fourth year Mechanical Engineering and fourth year Civil Engineering.

Pre-requisite courses: For Mechanical Engineering: M. E. **36**, M. E. **33**, C. E. **78**; for Civil Engineers, M. E. **77**, M. E. **78**, C. E. **75**.

52—Organization and Management. 2 hours. Professor RAUTENSTRAUCH and Associates.

Manufacturing Organizations and Methods of Cost Accounting—Effect of methods of manufacture and capacity on systems of management of mills and factories. Analysis of the elements of factory accounting and determination of the factors entering into the cost of production. Methods for keeping record of the cost of labor and materials in the production of specific articles. The determination of establishment charges. Interpretation of costs and use of comparative values. Determination of costs and use of comparative values. Determination of the depreciation of buildings, machinery, patterns, drawings and other assets. Organization and functions of the departments of the business. Purchase of raw material and sale of product. Utilization of scrap and waste. Methods of labor compensation. Critical analysis of the methods of accounting in representative factories. Factors affecting the cost of production. Layout of complete system of organization, forms, methods of accounting and progress of work for the factory designed in course M. E. **68**, Manufacturing Plant Design.

Fourth year Mechanical and Chemical Engineering.

Pre-requisites must parallel M. E. **68** for M. E.'s.

53—Steam Turbines. 2 hours. Professor PARR, Mr. STONE and Associates.

Fundamental Analysis of the Action of Steam Jets and Vanes and Its Application to the Design and Performance of Steam Turbines—Ratio of impulse to reactive force jets, effect of variation of curvature of the buckets, open and closed passages. Flow of steam through nozzles and turbine passages, volume, pressure, temperature, quality, weight, velocity and kinetic energy relations. Centrifugal effect of steam moving in a curved path. Study of the use of steam in varying types of turbines. Graded pressure turbines, graded velocity turbines, mixed impulse and reaction turbines. Practical turbines belonging to these types, and study of their detailed construction. Efficiency of different types studied by analysis of energy transformation throughout the path of steam and how efficiency is varied by design of blades, passages, nozzles, number of stages, speed, clearance, leakage and mode of regulation. Construction of turbine vanes. Disc and vane friction and critical speed. Governing steam turbines, throttling method, variable admission to one or more stages and periodic admission. Steam consumption of turbines. Book used: *The Steam Turbine*—Stodola.

Fourth year Mechanical and Electrical Engineering.

Pre-requisite courses: For Mechanical Engineers, M. E. **17-18**, M. E. **31-32**; for Electrical Engineers, M. E. **17-18**, M. E. **76**.

54—Shop Processes, Tools and Time Study. 2 hours. Professor RAUTENSTRAUCH, Mr. MILLER and Associates.

The Economic Elements in Shop Processes, Time and Power per Unit of Surface Finished or Cut and per Unit of Metal Removed with the Conditions for Most Economic Production—Processes in the shop, functional operation of machine tools and limits of economic production, time of setting, handling, forming and finishing of parts for job and repetition work in quantity. Limits of time, power and cost for finishing surfaces per sq. in. and removing per cu. in. and per lb. by hand and machine operations. Machines for performing specific operations, their functional operation, capacities, adaptability and rate of production. Conditions warranting jigs and fixtures for the production of parts in quantity and for interchangeability. Economy of portable tools, devices and methods of inspection. The selection of economic cutting conditions and analysis of recent experiments. Adaptation of economic cutting speeds to machine tools. Labor-saving devices in the pattern shop, tools and appliances used, capacity and adaptability; built-up patterns, single-piece patterns, metal patterns, comparative cost and life of each; patterns for repetition work, rights and lefts, a line of sizes, interchangeable patterns, jobbing patterns, relative economy of alternating practice. Economic production in the foundry, relative value of various methods of molding large and small parts, core making, venting, pouring and handling the work, managing the cupola. Limits of labor, power and fuel per ton of castings as affected by size and form and fraction chargeable to pattern, molding and cupola and finishing. Processes of forging, hand and machine, conditions warranting power hammers, hydraulic presses, bull-dozers, presses, dies and forming devices for the production of duplicate and standard pieces. Labor and power per lb. of forging as affected by tools, size and form of work. Heating and annealing furnaces, consumption of gas and oil, labor, power and fuel per unit annealed. Distribution of cost of machine production between different processes, power, labor, material and effect of shop or tool capacity factor on fixed charges.

Third year Mechanical Engineering.

Pre-requisite courses are M. E. 94S, T. C. Shopwork and M. S. 39.

56—Water Power Installations. 1 hour. Mr. HERRICK.

Selection and Arrangement of Water Wheels, Governors and Auxiliary Appliances for Different Local Conditions, Efficiency of Wheels and Plants—Characteristic of water flow through turbine guides, nozzles and buckets, conditions warranting wheel classification, efficiency of wheels as a function of type, head, speed and part gate operation, effects of different forms of gate on efficiency, relative value of standard patterns and special designs to suit local conditions, limits of standard dynamo speeds on wheel speeds. Water wheel governors regulation. Available head at wheels and division of total loss throughout water conductor system, relation between available water supply, possible output and perfection of development work; draft tubes, stop valves, gates, vacuum and pressure relief stand pipes, relief valves and bye-passes, water racks, anchor and frazil ice. Analysis of typical installations. Water power costs. Text: *Water Power Engineering*—Mead.

Fourth year Electrical Engineering.

Pre-requisite courses: C. E. 77. Parallel course: M. E. 60.

59—Empiric Design. 2 hours and 1 afternoon. Professor THOMAS.

Proportioning of Machine Parts by Empiric Methods and the Production of Shop Drawings and Sketches—Modern practice in making, recording and filing shop drawings of machine details and assemblies, bills of material and listing of standard and special parts. Use of standard conventions and interpretation of shop notes on drawings. Shop sketches and dimensions. Forms of machine parts as indicated by the nature of the resistances to be overcome and the characteristics of the material. Plain, box, and ribbed cast sections, shrinkage stresses and the probability of local weaknesses. Proportions of parts by modern empirical formulas derived from practical considerations. Limiting conditions in the use of empirical formulas. Modern practice in the proportioning of machine elements. Proportions of parts adopted by the Master Car Builders' Association, Master Steam Boiler Makers' Association, United States Government, numerous manufacturing concerns and data appearing in the transactions of the various engineering societies and engineering publications. Design of simple castings from assigned data, dies for forming simple parts in a bull-dozer and the frames and parts of simple machines having given the detailed drawing of the other parts necessary to the determination of the principal dimensions.

Second year Mechanical Engineering and third year Chemical Engineering.

The pre-requisite courses are Drafting 1 or 2.

60—Hydraulic Laboratory. 1 afternoon. Mr. HERRICK.

Practical Work on the Flowing of Water for the Determination of Rational Coefficients with Ordinary and Extraordinary Conditions—Flow through simple holes in plate and short tubes under low heads. Flow through convergent nozzles and needle orifice. Flow through straight pipe, elbows and joints, distribution across the cross section near bends with velocity. Flow through open channels. Flow over weirs. Variation of rectangular, trapezoidal and triangular, sharp versus dull edge, approach contractions, one side, both sides and bottom. Hook gauge measurements. Measurement of quantity flowing by Venturi tube and Pitot tube. Variation of error with type, pressure drop, and size. Loss of heads by sudden enlargement in cross section in pipes running full. Inertia and water shock. Water wheels. Variation of efficiency with speed and head, analysis of losses in nozzles, bucket and friction. Text: *Lecture Notes.*

Fourth year Electrical Engineering and third year Mechanical Engineering.
Parallel course: For Mechanical Engineers, C. E. **78.**
Pre-requisite for Electrical Engineers: C. E. **77.**

62—Refrigerating Machinery. 1 hour. Mr. THURSTON.

Relative Equipment, Space Occupied, Fuel and Water Consumption per Ton of Refrigeration or of Manufactured Ice for Principal Systems—Physical properties of anhydrous ammonia, carbonic acid, aqua ammonia, sodium and calcium brine solutions. Ammonia compression systems, wet and dry and oil injection systems. Liquid storage, pressure and liquid receiver tanks, pipe and fittings, expansion valves, direct expansion coils, double pipe, submerged and shell brine coolers, insulation of tanks and pipes, brine circulating pumps. Compressors. Ammonia condensers, atmospheric, double pipe and submerged, condenser water cooling towers, ammonia fore-coolers and oil coolers for oil system. Carbonic acid systems, characteristics and quantities compared with anhydrous ammonia. Ammonia absorption systems Absorber constructions, generator construction. Dense air systems. Air drying. Refrigerating rooms, brewery, meat, general stores, restaurants. Ice making. Can and plate systems, water purification systems, oil separators, steam condensers, reboilers, evaporators, single and multiple effect, skimmers, water storage tank and governors. Quantity of water per ton of ice, quantity of steam condensed from compressor and auxiliaries, available and make-up water. Text: *Compend. of Mechanical Refrigerating*—Siebel.

Third year Mechanical Engineering.

Pre-requisite course: M. E. **17.** Parallel course: M. E. **18.**

63—Hydraulic Laboratory. 1 afternoon. Mr. HERRICK.

Same as M. E. **60.** Fourth year Civil Engineering.

Parallel course: Hydraulics, C. E. **75.**

64—Air Machinery. 2 hours. Mr. LONGACRE.

Structures, Adaptability and Economy of Fans, Air, Gas and Vapor Compressors, Blowing Engines, Jet Blast Apparatus and Important Applications—Convection movement of air; flow of air through orifices, ducts, pipes. Hygrometric conditions of air with temperature and pressure and condensation of moisture in compressed air. Air compressors, types and construction; work of compression, M.E.P. for single and multi stage, cylinder ratios, effects of intercooling. Volumetric efficiency of compressors, real and apparent. Discharge pipe pressure pulsations, air receivers, intercooling receivers. Air end valves, poppet, slide, Corliss and ring valves, suction and delivery, differences in type and diameter and lift. Steam end valve gears and cylinder arrangement. Constant and variable speed compressor valve gear characteristics, pressure and speed controllers and governors. Analysis of complete compressor economy tests. Dry vacuum air pumps. Blowing engines, special forms and sizes of air end valves introduced by cylinders of large diameters for low pressure air. Ammonia and carbonic acid compressors; peculiarities and methods of handling liquid in the vapor; forms and characteristics. Multi-stage centrifugal fans and service. Analysis of efficiency tests for fans and blowers. Positive blowers. Steam jet blowers and exhausters, thermal efficiency. Application of principles to ventilation and heating, blast furnace practice, compressed air and compressed gas power transmission systems, air lift pumps and air brakes.

Third year Mechanical Engineering.

Pre-requisite course: M. E. **17.**

66—Elevators and Conveyors. 1 hour. Mr. Moss.

Mechanical Handling of Solid Materials by Standard Elevating and Conveying Machinery, Characteristics, Speed, Tonnage and H.P. per Ton, Computations and Adaptability to Special Service—Hand handling of materials, limits, cost and conditions warranting use of machinery. Continuous conveyors, screw, bucket, scrapers, pusher, belt and pneumatic types. Intermittent conveyors; telephers, rope and cable ways, cable cars. Loaders, unloaders, storage facilities. Skips, grab buckets, tips and tipples. Short and long hoists, friction drum hoists and direct connected. Pneumatic and hydraulic elevators for freight. Fixed and travelling cranes. Passenger elevators, rope and plunger types. Safety devices. Automatic weighers of materials; coal and ore storage systems. Excavating machine and dredges. Coal and ore-handling machinery. Railroad terminal and steamship loaders and unloaders. Coke oven chargers and dischargers. Grain handling. Special adaptation to material, such as sand, plaster, glass, cement, broken rock, coal, coke, packages, barrels, corrosive, erosive, sticky, packing, and hot materials.

Third year Mechanical Engineering.

Pre-requisite course: M. E. **39**.

68—Shops and Factories. 2 hours and 1 afternoon. Professor Rautenstrauch and Associates.

Methods of Procedure for the Design of a Plant for the Manufacture of an Assigned Product at a Given Rate—Determination of kind and quantity of materials needed, processes by which they may be most economically worked, selection of machinery for each process, determination of the number of each kind of machine required, power necessary to drive. Layout of shops for most direct production. Selection of facilities for handling, storing and shipping on the basis of economy effected. Grouping of pattern and machine shops, foundry, forge and general office; estimate of costs of equipment and installation. Layout of heating, ventilating and lighting systems, power transmission systems and facilities for reduction of fire hazard. Layout of system of management and cost determining system.

Fourth year Mechanical Enginering.

Pre-requisite course: E. E. **103**; and must be paralleled by M. E. **52**.

70—Pumping Machinery. 2 hours. Mr. Thurston.

The Mechanics of Moving Liquids and Standard Machinery for Pumping—Water elevators, conditions for high efficiency and limits of use. Displacement, piston and plunger pumps; forms and functions of water pistons and plungers, pump bucket forms and limits of use, volumetric efficiency of water ends. Valves for water end, mechanical, flap, poppet, ball, annular, flat, double beat type and relation, adaptability to fluid, speed and temperature; forms of valve seats, conditions for perfect flow, piston speed and water inertia. Air chambers. Suction limitations of altitude, water temperature and absorbed gases and acceleration. Peculiarities of high pressure work, accumulators. Fly-wheel pumps, steam end characteristics, relation between steam and water diameters and displacements. Direct acting pumps, valve motion in single types, full and partial steam throw valves for simple, compound and triple use of steam. Duplex direct acting pumps, structural and operating characteristics. Economy of direct acting simple and multiple expansion pumps. Centrifugal and turbine pumps, forms and operative characteristics. High duty pumping engines, conditions for maximum duty referred to steam and coal; pumping engine tests, methods of conducting and analysis of results obtained. Typical pumping engine installations. Pulsometer pumps. Jet apparatus, injectors, ejectors and eductors, construction and duty as pumps. Water relief valves, pressure and float pump governors.

Third year Mechanical, Civil and Chemical Engineering.

Pre-requisite course: M. E. **17**. Parallel C. E. **78**.

72—Gas Power Machinery. 2 hours and 1 afternoon. Professor Lucke.

Short course adapted from M. E. **22**.

Fourth year Electrical and Metallurgical Engineering.

Pre-requisite course: M. E. **17**.

SCHERMERHORN HALL

74—Gas Power Machinery. 2 hours. Professor LUCKE.

Same as 72 except the time.
Fourth year Mining Engineering.
Pre-requisite course: M. E. 17.

76—Standard Tests. 1 hour and 1 afternoon. Professor PARR and Mr. THURSTON.

Short course adapted from M. E. 31, 32, 33.
Third year Metallurgical, fourth year Chemical, third year Mining and third year Electrical Engineering.

Pre-requisite for Mining, Chemical, Metallurgical and Electrical Engineers: M. E. 13-14 and M. E. 17. Parallel for Electrical Engineers: M. E. 18.

77—Standard Tests. 1 hour and 1 afternoon. Professor PARR and Mr. THURSTON.

Short course adapted from M. E. 31, 32, 33.
Third year Civil, fourth year Chemical and fourth year Electrical Engineering. Pre-requisite for Civil and Chemical Engineers: M. E. 13-14 and M. E. 17; for Electrical Engineers, M. E. 17-18 and M. E. 76.

78—Kinematics. 1 afternoon. Professor THOMAS.

Short course adopted from M. E. 36.
Third year Civil Engineering. Pre-requisite: Math. 3-4.

82—Heating and Ventilation. 3 hours.

Principles of Heat Generation Transfer and Air Movement Applied to Warming and Ventilation of Buildings—Quantities of air needed for proper ventilation, amount of heat necessary to maintain temperatures against conduction, radiation and air change losses. Heating surface and coefficients of heat transfer, grate surface, pipe and duct sizes for high and low pressure steam heating, direct and indirect, hot water and hot air systems. Air tempering, cleaning, drying, humidifying. Pipe and duct layouts. Fan computations. Exhaust steam systems, vacuum circulation. Reducing valves, air valves, water expansion tanks, thermostats, thermostatic regulation systems and important details. Efficiencies of various systems and analysis of existing installations. Fourth year Sanitary Engineering.

94S—Shop and Factory Work. Professor RAUTENSTRAUCH.

Practical Work and Directed Study in the Shops and Drafting Rooms of Representative Manufacturing Establishments with Report—Each student is provided with a printed copy of the things to be studied and reported on in detail, of which the following is a general summary:

Machine Shop. Functional operation, characteristics and powering of machine tools, capacities, layout of shop, size of shafting, belting and motors for independent and group drive. Range of cutting speeds, feeds, depth of cut. Shape and size of tools used. Report on specific observations on time of setting work, time of forming and finishing, number of pieces turned out per hour. Facilities for handling work at the machine. Facilities for producing pieces in quantity. Hand processes for finishing and tools used.

Pattern Shop. Materials of which patterns are made and methods of treating. Machine tools used in the pattern shop arrangement, capacities, adaptability, handling and storing of material and finished product.

Foundry and Forge, Description of hand and machine tools and appliances used in the foundry and forge. Compositing and treatment of foundry sands. Methods of molding. Time involved. Methods of powering, venting and chilling, cooling and finishing, handling the cupola. Composition of the charges and mixtures, temperatures, pressures, time required to charge, to melt, to pour, cool and clean. Appliances in the forge shop. Operation of power hammers, bull-dozers, shears, heating and annealing furnaces and hand processes of forging. Time involved in production.

Drafting Room. Standards and conventions used. Filing and marking of drawings and recording of patterns. Bills of material—parts to be made—standard parts in stock.

General Management and Organization. Methods of recording time of workmen and their time distribution over on different jobs. Paying of men, methods, rates, forms and records used. Drawing of materials used from storeroom and charging to orders.

Pre-requisite course is second year shop work.

96S—Steam Power Plant, Summer Work. Professor LUCKE.

Report based on not less than six weeks' practical work in an Operating Power Plant, including the Output, Load Conditions, Labor and Material for Operation and Maintenance, Operating Cost per Unit and the Essential Dimensional Relations between the Various Units and Auxiliaries Producing this Result—This work is done entirely by the student in the field, his only assistance being the blank report form which is put in his hands after a brief lecture on leaving the University for the vacation.

Third year Mechanical Engineering. Pre-requisite courses: M. E. 17-18, 31-32.

METALLURGY

101—General Metallurgy. 3 hours first half of term. Professor KERN.

An introduction to general metallurgy; consideration of the methods. Object of the metallurgist, and application of physics and chemistry to the extraction, and to the treatment of the commoner metals. General classification of processes. Classification of fuels, and the selection of the most suitable fuels for certain purposes. The calorific value, and the temperature of combustion, of fuels. Preparation of charcoal and coke, and the recovery and utilization of their by-products. Artificial gaseous fuels, their preparation and metallurgical utilization. Properties of gases, and the metallurgical application of the laws of gases. Classification of furnaces, and the types of furnaces for specific purposes. Refractory materials, and their use in the construction of furnaces. Transmission of heat and the thermal efficiency of furnaces. Calculation of height, sectional areas, capacity and drafts of chimneys. Fuel economizers, and their application to metallurgical furnaces. High temperature measurements.

Third year students in Metallurgical Engineering. Fourth year students, Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Chemistry 3-4 and Physics 3-4.

111—Metallurgy of Copper. 3 hours, second half of term. Professor KERN.

The production of copper, its uses, and consumption. Properties of copper and its alloys. The ores of copper, and distribution. Characteristics of ores of the principal districts. Sampling, and preparation of copper ores for treatment, and cost of different methods of sampling. General outline of the metallurgy of copper. Roasting of copper ores; purposes; chemistry; and methods of roasting. The advantages, disadvantages, and comparative cost of roasting processes. Introduction to smelting copper ores in reverberatory, and in blast furnaces. Composition, physical properties, and characteristics of furnace products; blister copper, black-copper, mattes, speiss, slag, and flue-dust. Smelting in reverberatory furnaces; construction of reverberatory smelting furnaces, their capacity and efficiency. Calculation of reverberatory furnace charges. Converting of copper matte in reverberatory furnaces. Smelting of copper ores in blast-furnaces. Calculation of blast-furnace charges. "Pyrite" or "Raw Ore" Smelting. Converting of copper matte by the Mahnés process. Apparatus required for converting copper matte. Refining of blister copper, black-copper, and cement-copper. Smelting of typical copper ores, producing ingot copper; the handling, and the disposition of the furnace products; cost of treatment.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 101.

118—Metallurgy of Copper. 1 hour. Professor KERN.

Advanced Course. Treatment of low-grade ores, and of copper-silver ores by leaching. Recovery of copper from mine-water. Utilization of furnace-gas for the production of sulphuric acid. Treatment of copper-nickel ores. Metallurgical calculations of roasting operations. Application of thermo-chemistry to roasting and smelting, and to calculations of furnace efficiencies. Purchasing of copper ores and fluxes.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111.

122—Metallurgy of Lead, Silver, Gold and Zinc. 3 hours. Professor WALKER.

Properties of lead, its compounds and alloys. Classification of ores. Production and uses of lead. Outline of the metallurgical treatment of lead ores. Smelting in the reberberatory furnaces; in the ore-hearth. Blast furnace practice for smelting lead ores. Roasting in hand and mechanical furnaces. Various pot-roasting processes and sintering machines. Smelting operations; construction of furnaces; calculation of charge; disposition, handling and treatment of by-products. Desilverization of lead bullion. Influence of impurities and elimination of same. Cupellation of rich lead alloys and ores. Treatment of Dore. Silver. Its properties, compounds, alloys, etc. Direct amalgamation of silver ores. Hydro-metallurgical processes for treatment of silver ores; Ziervogel, Patera, etc. Gold. Properties, etc. Amalgamation of gold ores. Chlorination processes. Cyaniding of gold ores; laboratory tests, and chemistry of the process; modern practice, description of existing plants. Refining and parting of gold and silver bullion. Zinc. Properties, ores, etc. Calcination and roasting of zinc ores. Retorting furnaces. Manufacture of retorts; retorting practice and chemistry of same. Refining of zinc.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 111.

128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. 1 hour. Professor WALKER.

Advanced Course. Methods of receiving and sampling different classes of ore. Purchasing of ore of varying compositions. General construction of furnaces, and design of smelting plants. Organization of smelting plants; metallurgical bookkeeping, cost sheets, etc.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 122.

131—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Manufacture of iron and steel. Blast furnace. Puddling. Cementation. Crucible process. Bessemer process. Open hearth process. Statistics. Iron and steel casting. Effect of heat treatment. Effect of mechanical treatment. Malleable cast iron. Standard specifications. Constitution of iron and steel. Relation to physical properties. Change of structure with heat and mechanical treatment. Alloy steels. Corrosion.

Fourth year students in Mining and Metallurgical Engineering and Chemistry. Third year students in Chemical Engineering. Pre-requisite: Chemistry 3-4 and Physics 3-4. Pre-requisite or parallel: Metallurgy 101.

134—Metallurgy of Iron and Steel. 2 hours. Professors HOWE and CAMPBELL.

Introduction, literature, scheme of iron and steel manufacture. Definitions: iron, steel, cast iron, etc. Relations of carbon and iron. Development of the industry. The blast furnace, iron ores, fuels, fluxes, smelting practice, products. Processes for purification of pig iron. Manufacture of wrought iron and crucible steel. Puddling, charcoal hearths, fineries. Cementation, blister steel. Crucible process. Bessemer process, acid and basic. Siemens-Martin or Open Hearth process, acid and basic; fuels and regeneration. Defects in ingots and other castings. Iron and steel founding. Mechanical treatment of steel, forging, rolling. Heat treatment of steel. Heat treatment of cast iron. Malleable cast iron, cupola and air furnace. Alloy steels; nickel; vanadium; manganese; chrome; tungsten, etc. Self-hardening, high-speed steels.

Practical metallography of iron and steel. Macroscopic examination. Microscopic examination of wrought iron, pipe steel, low carbon and structural steel. Shafting, etc. Medium and high carbon, rails and tires. Tool steels. Cast irons. Comparison of good with bad material. Relation between structure and properties. Corrosion. Standard specifications. Electrometallurgy of iron and steel.

Second year students in Civil, Electrical, and Mechanical Engineering. Prerequisite: Chemistry 3-4 and Physics 3-4.

138—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Advanced Course. A detailed study of the constitution of iron and steel and the effects of heat and mechanical treatment upon the constituents. Discussion of the various processes of manufacture of iron and steel, alloys steels, etc. The iron and steel industry of the United States, Germany, England, and other countries. Standard methods of testing.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 131.

141—Electrometallurgy. 1 hour. Professor KERN.

Theory of the electric current, and its application in the treatment of ores, refining of metals, and production of refractory alloys. Theory of electrolysis; determination of efficiency. The solution pressure series of the metals, and its application in the refining of copper, lead, iron, nickel, antimony, tin, zinc, gold, and silver. Electrolytic refining of copper. Electrolytic refining of lead. Treatment of anode residual. Parting of silver and gold by electrolysis. Refining of gold alloys. Electrolysis of fused electrolytes; production of aluminum; treatment of sulphide ores, etc. Electric furnaces used: for smelting ores, for refining metals, and for manufacture of refractory alloys. Efficiency of electric furnaces; cost of constructing and maintaining.

Fourth year students in Mining and Metallurgical Engineering, and Chemistry. Pre-requisite: Chemistry 3-4 and Physics 3-4.

148—Electrometallurgy. 1 hour conference. Professor KERN.

Advanced Course. Construction of electrolytic refineries; calculations of current, and power efficiencies. Selection of most suitable electrolyte, and most economical current density. Labor-saving appliances. Electrolytic deposition of copper, lead, zinc, nickel, gold and silver from solutions obtained by leaching their ores. Production of solid deposits, and laws governing the same. Rôle of current density in the electrolysis of aqueous and fused electrolytes, and in the operation of electric furnaces.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 141.

151—Constitution and Properties of Alloys. 2 hours. Professor CAMPBELL.

Pyrometry and freezing point or cooling curves. Various types of curves and their meaning. Examples of the same. Constitution of the various binary alloys. Methods of manufacture of commercial alloys. Ternary alloys. The phase rule. Change of structure in the solid state, pure metals, alloys, bronze, brass, steel. Methods of metallographic research.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111; Parallel Metallurgy 131.

155-6—Metallography. Iron, Steel and Industrial Alloys. Six lectures and 3 or more afternoons laboratory. Professor CAMPBELL.

Methods of examination. Comparison of good and bad material; wrought iron, low carbon steel, structural steel, rail steel, tool steel, etc. Examination of brasses, bronzes, bearing metals and other industrial alloys. Relation between chemical composition, physical properties and microstructure.

Course for students in Mechanical Engineering, and for special students. Pre-requisite: Metallurgy 131 or 134.

158—Advanced Course on Constitution and Property of Alloys. 1 hour. Professor CAMPBELL.

Pre-requisite: Metallurgy 151.

62S—Summer Course in Non-Ferrous Metallurgy. Professor KERN.

For description see page 37. 1 week field work at metallurgical plants during the summer.

Instruction for this field work will be given in five one-hour conferences during the last week in April.

Third year students in Mining Engineering.

64S—Summer Course in Ferrous Metallurgy. Professor CAMPBELL.

For description see page 37. Third year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 101.

66S—Summer Course in Non-Ferrous Metallurgy. Professor KERN.

For description see page 37. Third year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 122.

72—Metallurgical Laboratory. 10 consecutive afternoons, second term. Professor CAMPBELL and Professor KERN.

Calibration of Le Chatelier pyrometer. Cyaniding and chlorination of gold ores. Roasting of copper matte, and use of pyrometer. Desilverizing of base bullion by Parke's process. Microscopic metallography. Thermal treatment of steels.
Fourth year students in Mining Engineering.
Pre-requisite: Metallurgy **111.** Parallel: Metallurgy **122.**

171-172—Metallurgical Laboratory. 5 afternoons. Professors WALKER, CAMPBELL and KERN.

Calibration and comparison of thermo-electric, optical and radiation pyrometers. Determination of the calorific power of fuels by the Mahler-Berthelot calorimeter. Microscopic study of metals and alloys. Thermal and mechanical treatment of steels and cast iron. Roasting of copper matte, and use of pyrometer. Production of blister copper by the reaction process. Refining of blister copper. Desilverization of base bullion by Parke's process. Cyaniding of gold and silver ores. Chlorination of gold ores. Electrolytic refining of copper and lead bullion. Fusibility of slags and refractory materials.
Fourth year students in Metallurgical Engineering. Parallel: Metallurgy **101** and **111.**

173-174—Metallurgical Laboratory.

Special work along the lines indicated under the head of Metallurgy **201-202.** This work is intermediate between that of Metallurgy **171** and **201-202** and is designed for those desiring to take an advanced metallurgical laboratory course without confining themselves to special research work.

175—Metallurgical Investigation. 1 hour conferences. Professors WALKER and CAMPBELL.

Fourth year Metallurgical Engineers. Pre-requisite: Metallurgy **122.** Pre-requisite or parallel: **131, 141.**

177—Metallurgical Plant Construction. Professor WALKER.

General design of metallurgical plants and problems entering into the construction of same.
Special work is assigned to each student, which is carried on under direct and constant supervision in the drafting room and laboratories. The experience gained in visits to metallurgical plants is brought into practical use.
Fourth year Metallurgical Engineers. Pre-requisite: Drafting **3-4, 7-8;** Civil Engineering **53;** Metallurgy **122, 64S** and **66S.**

Graduate Courses

Special courses, consisting of original research, will be arranged for advanced students according to their individual needs and abilities. Most of these researches will consist of work in the departmental laboratories, but others will consist of study, and still others of work in industrial establishments.

The following list shows what subjects are suited to these courses:

201-202 (*a*)—Advanced work on some problem in general metallurgy, as for example:

In Calorimetry: Determination of the calorific power of fuels, or testing some law in calorimetry;

In Pyrometry: Determination of the temperatures of metallurgical and other industrial high-temperature operations;

On Refractory Materials: Their resistance to heat and corrosion; their tendency to slack; their contraction and expansion, etc.;

On Slags: The formation points, melting points, flowing points, and their density and viscosity when molten;

(*b*)—In the Metallurgy of Copper:

The chemistry of roasting processes, such as the elimination of arsenic and sulphur; chloridizing and sulphate roasting, etc.

The reactions of smelting processes;

Wet methods of extraction;

(*c*)—In the Metallurgy of Lead, Silver, Gold, etc.:

The pot-roasting of sulphides, and others mentioned above under (*b*);

(*d*)—In the Metallurgy of Iron and Steel:

The effect of various constituents on Iron and Steel.

The heat and mechanical treatment of Iron and Steel; effect on physical properties and microstructure.

The study of alloy steels and the effect of heat treatment.

Case hardening, etc.

(*e*)—In Electro-metallurgy: Testing electro-metallurgical principles, refining, extraction and depositing process;

(*f*)—On Alloys: The constitution and properties of alloys, embracing a microscopic, pyrometric and mechanical or physical examination with a correlation of the results;

(*g*)—In Metallography: Metallography of iron, steel, industrial alloys or metallurgical products, as mattes, slags, etc.

Pre-requisite for 201-202: Metallurgy **122, 131, 141 and 171, or equivalent.**

MINERALOGY

1-2—Descriptive and Determinative Mineralogy. 3 hours lectures. 6 hours laboratory first term, 3 hours laboratory second term. Professors Moses and Luquer and Assistants.

The elements of crystallography. The blowpipe analysis of ores and other substances. The study of the important minerals, the purpose being: 1st. Sight recognition of average specimens of all common or economically important species; 2d. Rapid determination of the less characteristic specimens by simple tests; 3d. Familiarity with economic characters.

Pre-requisite: Entrance requirements in Chemistry and Physics. Prescribed course for students in Mining.

5—The Minerals of Building Stones. 2 hours lectures and 1 afternoon laboratory. Professor Luquer and Assistant.

Study of common species, their properties, methods of determination, and their economic effect on building stones.

Prescribed for students in the course of Civil Engineering.

6—Optical Mineralogy. In sections, 2 afternoons per week for first seven weeks of term. Professor Luquer and Assistant.

Principles, apparatus, and distinguishing characters of minerals in thin sections. Consists principally in the determination of minerals in rock sections by the aid of the polarizing microscope. Supplements Courses **5** and **1-2** and is preliminary to Geology **4** (petrography).

Pre-requisite: Course **5**, or part of Course **1-2**, or the equivalent. Prescribed for students in Mining.

7-8—Descriptive and Determinative Mineralogy. 3 hours lectures, 3 hours laboratory. Professors Moses, Luquer and Assistants.

Modification of Mineralogy 1. Lectures identical, laboratory work condensed. Prescribed course for students in Metallurgy.

15-16—Mineralogy. 3 hours laboratory. Professor Moses and Assistant.

Sight recognition and determination of minerals important in the chemical industries.

Pre-requisite: Chemistry A and Physics A. Prescribed for students in Chemistry and Chemical Engineering.

MINING

Undergraduate Courses

51—Excavation and Tunneling. 3 hours, third year. Professor Peele.

Excavation of earth: tools and methods employed, support of excavations, special methods for quicksand and other water-bearing material; steam shovels and other mechanical excavators; handling and transportation of excavated material; comparative costs. Explosives: black powder, nitro-glycerine and its compounds, and other high explosives; their composition, manufacture, and use. Excavation of rock: methods of drilling and blasting mammoth blasts, submarine blasting. Railroad tunnels: methods of driving and timbering; handling and transportation of excavated material; drainage and ventilation; lining of tunnels, submarine tunnels. Mine tunnels; examples from practice; sizes, details of driving, timbering, rates of advance and costs.

Required of students in the course of Mining Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry, and Physics.

52—Boring and Shaft Sinking. 2 hours, third year. Professor Peele.

Boring: methods and appliances for small depths and for deep boring; rod boring and cable tool or oil-well method; boring with core drills, for prospecting and other purposes; survey of bore-holes. Shaft sinking: methods and tools employed in soft material and in rock; sinking linings or drop-shafts, freezing and other special methods of sinking in soft water-bearing formations; drainage of shafts; handling and hoisting of excavated material. Shaft timbering, walling, tubbing, and other forms of lining. Costs of shaft sinking.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51.

53—Excavation, Tunneling, Boring and Shaft Sinking. 2 hours, second year. Mr. Judd.

A condensation of courses 51 and 52, in which attention is given only to those operations that are of special interest to the civil engineer. Excavation and transport of earth for structural purposes and railroad grading; steam shovels and dredges. Explosives. Excavation of rock; methods of drilling and blasting; submarine blasting; railroad tunnels; quarrying; testing for foundations in earth, rock and watery material; well drilling; shaft sinking by usual and special methods.

Required of students in the course of Civil Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry and Physics.

54—Exploration, Development, and Methods of Working. 3 hours, third year. Professor Munroe.

Mineral deposits, characteristics of beds, masses, veins, and other deposits, and the irregularities and disturbances to which they are subject, as affecting the work of exploration and mining. Examination and survey of mineral properties; relation of topography to geological structure; construction of maps and sections; and tracing of probable outcrops as a guide to exploration. Prospecting by ditches, pits, and deep boring. Development; choice of methods; location of openings. Working of deposits and support of excavations; theoretical considerations, methods

of breaking ground in coal and metal mining, and support of mine excavations by pillars of mineral, by timbering, by masonry, and by rock filling; methods of working applicable to deposits of different thickness, inclination, and character. Coal mining; vein mining; working of thick deposits and soft-ore bodies. Salt mining. Surface working. Hydraulic mining and gold dredging.

Required of students in the courses of Mining and Metallurgical Engineering. Pre-requisite: Geology 5-6. Pre-requisites or parallels: Geology 105-106, Mining 51 and 52. Accepted together with Mining 81 and 82, or with Mining 56 and 91, as a minor for the degree of A.M.

56—Mine Engineering. 3 hours, fourth year. Professor MUNROE.

Ventilation; air of mines; mine gases; methods of ventilation; control and measurement of air currents. Drainage: sources of mine waters; methods for the control and raising of water; dams; drainage levels. Water supply. Surface handling and transportation; arrangements for loading and unloading cars and vessels, and for storing of minerals. Mineral railroads. Common roads. Accidents to men in shafts, levels and working places; fire-damp and dust explosions; mine fires; inundations; rescue and relief of men. Mine surveying, mine maps and models. Examination, sampling and valuation of mines.

Required of students in the course of Mining Engineering. Pre-requisites or parallels: Mining 54 and 71-72, Civil Engineering 76 and 28. Accepted together with Mining 54 and 91, as a minor for the degree of A.M.

71-72—Mine Plant. 3 hours, fourth year. Professor PEELE.

Description and critical discussion of the machinery and appliances employed in the equipment of mines; design, erection and care of plant. Hoisting: engines, drums, wire rope, skips and cages, head-frames; calculation of power required and methods of equalizing the load on the engine; shaft-sinking plant, over-winding. Drainage: buckets, tanks and hand-pumps; Cornish and direct-acting underground pumps; operation of pumps by electricity, compressed air, and hydraulic power. Centrifugal pumps. Ventilation: underground furnaces, positive blowers, and centrifugal fans; theory and efficiencies of fans. Air compressors: simple and compound (stage) compression; methods of dealing with heat of compression; conveyance of compressed air in pipes; reheating; operation of machinery by compressed air; efficiencies. Machine drills; coal-mining machines or coal-cutters. Handling mineral in working places. Mine cars; arrangement and construction of tracks. Underground haulage; hand tramming; mule haulage; gravity roads; steam, compressed-air, and electric locomotives; rope haulage; efficiencies; comparison of systems of haulage.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51, 52 and 54, and Mechanical Engineering 13-14. Accepted together with Mining 73 and 75, as a minor for the degree of A.M.

73—Mine Constructions. 1 hour, fourth year. Professor PEELE.

Building-stones; bricks; limes; cements and concretes. Foundations of various soils; retaining walls; masonry and timber construction, with special reference to mine work; mine buildings; trestles; ore-bins.

Required of students in the courses of Mining and Metallurgical Engineering. Accepted together with Mining 71-72 and 75, or with Mining 81, 82 and 75, as a minor for the degree of A.M.

75—Design of Mine Plant. 4 afternoons, fourth year. Professors PEELE and KURTZ and Mr. JUDD.

The students are assigned problems in the design and construction of mine plant, in connection with the development of a mine. This work supplements the lectures on the design of mining machinery, involving reading and study, and the preparation of working drawings, covering certain portions of the plant, together with bills of material, specifications, and estimates. As these drawings are intended to accompany and illustrate in part the graduating theses or projects, the designs are made in accordance with the subjects and conditions therein assigned. The work is done under constant supervision and advice in the draughting-room.

Required of students in the course of Mining Engineering. Pre-requisite: Drafting 3-4, 7-8, Civil Engineering 53. Parallel: Mining 71-72. Accepted together with Mining 71-72 and 73, or with Mining 81, 82 and 73, as a minor for the degree of A.M.

77-78—Graduating Thesis or Project. Professor PEELE (see page 37).

Mining Thesis

The subjects for the graduation theses are assigned during the third year, and are made a part of the regular course of instruction. The subject given in each case is the problem of the opening and development of a mine, supposed to be located in some well-known mining district, and for which certain definite conditions as to size and character of ore body, amount of water to be pumped, and quantity of ore to be mined, are assumed. During the summer field work in mining the student incidentally obtains data for his thesis work. This information is supplemented by study of books and technical literature. During the fourth year he decides upon the proper methods for opening, developing, and working the property; and makes estimates of the plant, machinery and capital required, the cost of working, and the probable profits. He also works out in detail certain portions of the proposed mine plant, and prepares a set of working drawings, bills of materials and specifications therefor. This work, done under the supervision of competent instructors, constitutes both a review and a series of practical applications of the preparatory studies and enables the students to discover and remedy their deficiencies, giving them confidence in their ability to work out similar problems later.

Required of students in the course of Mining Engineering. Pre-requisites or parallel: All the required courses in Mining.

80—Mill Constructions. 1 hour, fourth year. Professor KURTZ.

Installation and operation of mechanical power transmission and auxiliary machinery in works for the mechanical treatment of minerals. Dealing with shafting, bearings, pulleys, belting, rope drives, gearing, etc.

Pre-requisite: Mechanical Engineering 13-14.

81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. 4 hours, fourth year. Professor MUNROE.

The general principles and theory of dressing; preliminary operations; hand dressing; cleansing; crushing; jigging with and without preliminary sizing; slime concentration; magnetic and electro-static separation; oil and flotation processes; milling of gold and silver ores; descriptions of typical dressing works and coal-washing plants in this country and abroad.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisites: Mineralogy 1-2, Physics 3-4. Pre-requisite or parallel: Mechanics 102. Accepted together with Mining 54 and 82, or with Mining 82, 73 and 75 as a minor for the degree of A.M.

82—Ore-dressing Laboratory. Afternoon work for three weeks, fourth year. Professors MUNROE and KURTZ and Mr. JUDD.

Mechanical testing of ores by laboratory methods; working tests with simple apparatus; adjustment and operation of concentrating machines.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite or parallel: Mining 81. Accepted together with Mining 54 and 81, or with Mining 81, 73 and 75, as a minor for the degree of A.M.

91—Mine Administration. 2 hours, fourth year. Professors MUNROE and KURTZ.

Administration, organization, and business management, mine accounts, and cost sheets.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mining 54. Parallel: Mining 56. Accepted together with Mining 54 and 56, as a minor for the degree of A.M.

94—Mining Law. 2 hours, fourth year. Professor KURTZ.

General principles of real estate law. Historical review of mining laws of various countries. Federal laws, concerning locations on public lands of the United States. State and territorial mining laws.

Pre-requisite: Civil Engineering 27, Mining 54.

95—Mining Conference. 1 hour. Mr. JUDD.

(Optional.) Reading and discussion of papers by the students, on mining practice and based on data accumulated in the course of the summer work in mining.

Summer Courses

58—Summer Class in Mine Surveying is held in June, at a mine in a near locality, and lasts one week. Professors MUNROE and KURTZ and Mr. JUDD.

59—The Summer Courses in Practical Mining. Professors PEELE and KURTZ and Mr. JUDD.

Held in June and July, at some mine or mines selected for the purpose, in the vacation between the third and fourth years, and lasts six weeks (for details see pages 29, 30).

Pre-requisites or parallels: Mining 51, 52 and 54, Civil Engineering 15, 27 and 28, Mechanical Engineering 13 and Geology 105-106.

Graduate Courses

Special courses, consisting of personal instruction, reading and experimental investigation, will be arranged for advanced students according to their individual needs and ability. These investigations will be made at mines and dressing works either in connection with the Summer class or elsewhere as assigned. with additional work, as required, in the library and in the laboratories of the department. These courses vary in difficulty and in the amount of time necessary, according as the student is a candidate for the degree of A.M. or Ph.D., and according as he pursues mining as a major or a minor subject. The time required is governed by the rule that a course or courses should occupy about 18 hours (outside reading and study included) per week if taken as a major subject, and about 9 hours per week if taken as a minor subject. Any of the following may be offered as a minor for the degree of A.M. by students who have had the appropriate prerequisites:

101-102—Mining and Ore Dressing. Mining 54, 81 and 82. 4 hours, with laboratory work and reading as required.

103-104—Mining Engineering. Mining 54, 56 and 91. 4 hours lectures and reading as required.

105-106—Design of Mine Plant. Mining 71-72, 73 and 75. 3 hours and 4 afternoons drafting-room work.

107-108—**Design of Ore-dressing Works.** Mining 80, 81, 82, 73 and 75, with 1 hour conference additional first half-year. 3 hours and 5 afternoons laboratory and drafting-room work.

109-110—**Mining.** All the undergraduate courses in the Department of Mining.

Under the regulations for the degrees of A.M. and Ph.D. the following courses may be offered by graduate students who have had all the undergraduate courses in mining or their equivalent.

201-202—**Methods of Mining.** Critical study of methods used in some mining region, or for a certain class of deposits; output per man, amount of timber and explosive required, and other details affecting cost. Study of conditions as determining choice of method. Determination of loss of mineral in mining. Accidents to men.

203-204—**Mining Plant.** Critical study of rock drilling, or coal cutting, or hoisting, or haulage, or ventilating plant at some mine or mines. Determination of efficiency and conditions affecting same.

205-206—**Deep Mining.** Study of problems of deep mining, vertical versus inclined shafts, hoisting and pumping from great depths, temperature and ventilation, efficiency of labor, rock pressure as affecting methods of mining and timbering.

207-208—**Ore Dressing.** Critical study of some detail of the ordinary dressing methods, crushing, or screening, or classification, or jigging, or slime treatment, or dry concentration, or magnetic separation, or milling of gold or silver ores, or mechanical preparation of coal. Determination of efficiency, and of conditions essential to success.

209-210—**Examination of a Coal-washing Plant, or of an Ore-dressing Plant.** 4 to 6 weeks' work in the mill and in the laboratory, with conferences.

211—**Examination of a Mineral Property, or a Mine.** 4 to 6 weeks devoted to field and underground work in the summer school of practical mining, with conferences at convenience of professor.

213-214—**Economic Studies in Mining.** Study of existing conditions affecting the production and cost of some mineral or metal, as, for example, anthracite coal, copper, or gold.

PHYSICAL EDUCATION

A1-A2—**Physical Education.** 7 lectures on personal hygiene. During the remainder of the year 2 hours a week of athletics and elementary graded gymnastic exercises. Dr. Skarstrom.

B1-B2—**Physical Education.** 7 lectures on sanitation and personal hygiene. During the remainder of the year 2 hours a week of athletics and graded gymnastic exercises. Professor Meylan and Assistants.

PHYSICS AND MECHANICS

Mechanics 1—Statics. 2 hours. Professors BURNSIDE, HODGE, PEGRAM, and Dr. WEBB.

Class is divided into small sections for recitations. Coplanar Statics is treated by both algebraic and graphical methods. Text: Maurer's *Technical Mechanics.*

Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 3-4—General Physics: Mechanics, Wave-Motion, Heat and Light. 3 lectures and 2 recitations. Professor WENDELL, Dr. MORSE, Mr. FARWELL, Mr. SEVERINGHAUS, Mr. NELMS, Mr. SCOTT.

Mechanics—Newton's laws of motion; accelerated linear and angular motions; dimensions; systems of weights and measures; energy, work, power; transformations of energy; conservation of energy; curvilinear motion with applications; gravitation; linear and angular simple harmonic motion; pendulum; wave-motion; sympathetic vibrations; elements of hydrostatics.

Heat—Nature of heat; expansion; thermometry; calorimetry; specific heat; mechanical equivalent of heat; change of state; saturated vapors and hygrometry; continuity of state; conduction; convection; radiation.

Light—General discussion of wave-theory; reflection; refraction; total reflection; index of refraction and measurement; lenses; dispersion; spherical and chromatic aberration; optical instruments; photometry; color; fluorescence and phosphorescence; radiant energy; spectrum analysis; polarization of light.

Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 5—Electricity. 3 lectures and 2 recitations. Professor WENDELL and instructors.

Phenomena of electrostatics; capacity and condensers; electrometers; current electricity and methods of production; Ohm's law with applications; Joule's law with applications; thermo-electricity; magnetic action of currents with applications; electrical units; electro-magnetic induction; inductance.

Required of all second year students in Engineering. Pre-requisite: Physics 3-4.

Physics 43-44—Physical Laboratory. 3 consecutive hours a week throughout the year. Professor WENDELL, Dr. MORSE, Mr. SEVERINGHAUS, Mr. NELMS, Mr. SCOTT, Mr. HINES, Mr. JACKSON.

This course consists of quantitative experiments with reports in mechanics, light, heat, electricity, and magnetism. Methods of computation, plotting and the precision of measurements are discussed in connection with the experiments.

Pre-requisite: Physics 3-4. Parallel: Physics 5.

Physics 105—Physical Measurements. 2 hours. Professor HALLOCK.

Critical discussion of physical measurements and computations.

Pre-requisite: Physics 3-4. Parallel: Physics 5.

Mechanics 102—Mechanics. 5 hours. Professors BURNSIDE, HODGE, PEGRAM and Dr. WEBB.

This course is a continuation of Mechanics 1, using the same text book. The class is divided into small sections for recitations. Statics is completed; centers of gravity and moments of inertia of areas treated with aid of calculus; displacement, velocity, acceleration, motions of translation and rotation, work and energy, power, efficiency, impulse and momentum are all treated with special reference to engineering problems.

Required of all second year students in Engineering. Pre-requisite: Mechanics 1, Physics 3, and Mathematics 64-65.

Mechanics 101—Mechanics. The same course as Mechanics 102, but given in the first term.

Mechanics 105—Thermodynamics. 2 hours. Professor WILLS.

An idea of the nature of the course may be obtained from the following topical headings: The nature of heat; thermometry; calorimetry; heat and work diagrams; the First Law; applications to gases, perfect and actual; the work of Carnot; the Second Law; the Kelvin absolute scale of temperature; the combination of the two laws; application to the problem of change of state; the properties of saturated and superheated steam; theory of the "plug experiment"; the flow of fluids from crifices.

Pre-requisite: Mechanics 102.

Mechanics 107-108—Theory of Electricity and Magnetism. 2 hours first half-year, 3 hours second half-year. Professor WILLS.

The fundamental principles of electricity and magnetism are developed and discussed with particular reference to the bearing which they have in relation to the science of electrical engineering. The course concludes with an introduction into the theory of alternating currents.

Pre-requisite: Mechanics 102.

Mechanics 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits. 4 hours first half-year, 3 hours second half-year. Professor PUPIN.

Pre-requisite: Mechanics 107-108.

Mathematical Physics 201—Mechanics. 4 hours. Professor WILLS.

An advanced course on Mechanics developed with special reference to the general methods of d'Alembert, Lagrange, Jacobi and Hamilton.

Mathematical Physics 205—Electricity and Magnetism. 4 hours. Professor PUPIN.

Fundamental phenomena; derivation of Maxwell's equations; electrostatics; magnetostatics; stationary states; variable states; dynamical phenomena.

Mathematical Physics 206—Theory of Electrical Circuits. 4 hours. Professor PUPIN.

Briefly stated, this course covers advanced electro-mechanics, that is, the mathematical theory of generation and distribution of electrical power by variable electromotive forces. It deals with the theory of construction of alternating current generators, motors, and transformers, and with the theory of the construction of transmission lines for power distribution, telegraphy and telephony; also with wireless signalling.

Mathematical Physics 211-212—Partial Differential Equations of Physics. 4 hours. Professor WILLS.

Laplace's Equation; Poisson's Equation; Equation of Heat Conduction; Telegrapher's Equation; Fourier's Series; Spherical Harmonics; Bessel's Functions.

For other courses in physics and mathematical physics the student is referred to the *Announcement of the Division of Mathematical and Physical Science.*

SHOP WORK

The shop work is done in the Macy Building, which has full modern equipment, including the best types of improved machine tools for wood working and metal working in shops that provide for groups of twenty to twenty-four students to a section.

Shop work in wood is planned to lead up to pattern making and foundry work. The equipment includes benches for joinery and pattern making with the necessary hand tools and individual speed lathes for wood turning, a motor-head speed lathe of large size, 36-inch band saw and trimmers of the most recent type. There are also available for working up stock and special projects a saw bench, surfacer, jointer, mortising machine, all of the latest type.

Shop work in metal includes foundry, forging and machine-shop practice. The foundry contains molding benches for twenty students, and necessary tools for all kinds of bench work in snap flasks, floor molding, loam work, and the application of sweeps to the making of molds, together with melting pits for the melting of brass and bronzes and a cupola for melting cast iron. In the forge shop there are twenty forges with anvils, tools and vises, a 30-pound Bradley power hammer and a 400-pound Billings and Spencer drop-press. The machine shop contains lathes, swinging from twelve to twenty inches, planers, drill-presses, universal milling machines, and grinding machines, with examples of direct-connect motor and belt drives for each. A Jones and Damson flat turret-lathe and a Warner and Swasey screw machine are used for demonstrating modern methods of economical repetition production. In conjunction with all the shops there is a well-equipped tool-room, the attendance record is kept by a time-keeper's recording clock, and the organization and atmosphere of a commercial shop are aimed at.

1—Wood-turning and Pattern-making. 2 afternoons. Mr. Ross.

Shopwork, demonstrations and shop visits. The construction of typical patterns and core boxes, solid, split and piece, involving the use of bench tools and turning lathe. Mechanical Engineering. Second year.

2—Molding and Foundry Practice. 1 afternoon. Mr. Sleffel.

Shopwork, demonstrations and shop visits. Bench molding with type patterns, swept work in green sand and loam and molding in dry sand. Mechanical Engineering. Second year.

10S—Machine Work. Mr. Walsh.

As below. Mechanical Engineering. Section I, three weeks in June; Section II, three weeks in September. Second year.

11—Machine Work. 2 afternoons, third year. Mr. Walsh.

Shopwork, demonstrations and shop visits. Practical work with the lathe, planer, drill, shaper, milling machine, grinder and turret lathe. Assembling, erection and rigger's work. Mechanical Engineering.

12—Forging. 2 afternoons. Mr. Sleffel.

Shopwork, demonstrations and shop visits. Management of fire, shaping, drawing, upsetting, swaging, welding, tempering and die-forging. Work on drop and helve hammers. Mechanical Engineering. Second year.

13-14—Machine Work. 1 afternoon. Mr. WALSH.

As above. Electrical Engineering. Second year.

15—Forging and Foundry Practice. 1 afternoon. Mr. SLEFFEL.

As above. Civil Engineering. Second year.

16—Machine Work. 1 afternoon. Mr. WALSH.

As above. Civil Engineering. Second year.

18S—Pattern-making, Forging, and Machine Work. Three weeks in June. Mr. ROSS, Mr. SLEFFEL and Mr. WALSH.

As above. Chemical Engineering. Second year.

ZOOLOGY

7—Sanitary Biology. 2 afternoons for 6 weeks. Professor CALKINS and Assistant.

General principles of biology. Biological activity—function, metabolism, symbiosis, etc.; special biology—unicellular animals and plants of drinking waters, causes of trouble, etc.

Pre-requisite: Bacteriology **101**.

SCHEDULE OF PRE-REQUISITES FOR SUBJECTS UNDER THE FACULTY OF APPLIED SCIENCE

Astronomy

Subject	Pre-requisite
105—Geodesy. (For C. E.)	Math. 64-65 (Differential and Integral Calculus)
106—Geodesy. (For C. E.)	Astron. 105 (Geodesy)
107—Geodesy. (For C. E.)	Astron. 106 (Geodesy)

Botany

7—Growth and Character of Timber

Chemistry

Subject	Pre-requisite
3-4—General Inorganic	Entrance Chemistry or Chem.A.
7-8—Inorganic	Chem. 21-22 (Elementary Physical Chemistry) Chem. 163-164 (Quantitative Analysis) Chem. 83-84 (Industrial Chemistry) Chem. 101-102 (Advanced Inorganic) Chem. 171 (Organic and Sanitary Analysis) Chem. 170 (Assaying) Chem. 183-184 (Industrial Electro-Chemistry)
101-102—Advanced Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
21-22—Elementary Physical Chemistry	Chem. 3-4 (General Inorganic) Phys. 3-4 (Elementary Mechanics and General Physics)
121-122—Physical Chemistry	Chem. 65 (Quantitative Analysis) Phys. 3-4 (Elementary Mechanics and General Physics) Math. 64-65 (Differential and Integral Calculus)
38—Theoretical Electro-Chemistry	Chem. 65 (Quantitative Analysis, Inorganic) Phys. 3-4 (Elementary Mechanics and General Physics) Math. 64-65 (Differential and Integral Calculus)
23-24—Physical Chemistry	See 121-122
41-42—Organic, lectures	Chem. 3-4 (General Inorganic)
43-44—Organic laboratory	Chem. 41-42 (Organic) or parallel
141-142—Organic, general	Chem. 21-22 (Elementary Physical Chemistry) Chem. 161-162 (Quantitative Analysis, Inorganic)
143-144—Organic, conferences	Chem. 141-142 (Organic) or parallel
150—Advanced Organic. (For Chem. E.)	Chem. 41-42 (Organic)
61 or 62—Qualitative Analysis *Parallel* Chem. 3-4 (General Inorganic)	Entrance Chemistry or Chem.A.
65—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
66—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
161-162—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
163-164—Quantitative Analysis	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
167-168—Advanced Inorganic Analysis	Chem. 101-102 (Advanced Inorganic) Chem. 121-122 (Physical Chemistry) Chem. 163-164 (Quantitative Analysis)

Subject	Prerequisite
Chemistry (*Continued*):	
171—Organic and Sanitary Analysis	Chem. 41-42 (Organic) Chem. 161-162 (Quantitative Analysis, Inorganic)
173-174—Advanced Organic Analysis	Chem. 171 (Organic and Sanitary Analysis) or equivalent work in Chem. 271-272 (Special methods of Organic Analysis)
176—Chemistry of Food and Nutrition	Chem. 41 (Elementary Organic)
69 or 170—Assaying	Chem. 3-4 (General Inorganic) Chem. 61-62 (Qualitative Analysis) Min. 1 (Descriptive and Determinative Mineralogy) or Min. 7 (Descriptive and Determinative Mineralogy)
160—Special Methods of Assaying Ores, Alloys and Furnace Products	Chem. 69 or 170 (Assaying)
81-82—Industrial Chemistry, general course	Chem. 3-4 (General Inorganic)
83-84—Industrial Chemistry, special course	Chem. 81-82 (Industrial Chemistry)
88—Industrial Chemistry, laboratory practice	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
89—Industrial Chemistry, laboratory practice	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
95-96—Industrial Chemistry 97—Chemical Factory Construction and Apparatus 98—Chemical Factory Apparatus and Machines 80a—Factory Inspection and Summer Memoir. (For Chem. and Chem. E.) (Second Year) 80b—Factory Inspection and Summer Memoir. (For Chem. and without memoir for Chem. E.) (Third Year)	Chem. 3-4 Chem. 61 or 62 Chem. 41-42 Chem. 65 or Quantitative
93-94—Electro-Chemistry	
181 or 182—Practical Electro-Chemistry	Chem. 65 (Quantitative Analysis, Inorganic)
183-184—Industrial Electro-Chemistry	Chem. 65 (Quantitative Analysis, Inorganic)
Civil Engineering	
2—Theory of Surveying	
15—Surveying (between First and Second Years)	C.E. 2 (Theory of Surveying)
21—Highway Engineering	
23—Theory of Railroad Surveying	C.E. 15 (Surveying)
25—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
26—Surveying (between Third and Fourth Years)	C.E. 25 (Surveying)
27—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
28—Surveying (between Second and Third Years)	C.E. 23 (Theory of Railroad Surveying) C.E. 27 (Surveying)
51-52—Theory of Railroad Surveying	C.E. 15 (Surveying)
53-54—Elasticity and Resistance of the Materials of Engineering	Mech. 102 (Analytical Mechanics)
55—Standard Methods of Water Analysis	Zoology 7 (Sanitary Biology) C.E. 59 (Sanitary Engineering)
57a—Statistics and Interpretation of Water Analysis	Zoology 7 (Sanitary Biology) C.E. 59 (Sanitary Engineering)
57b—Drainage of Marshes and Lowlands	Zoology 7 (Sanitary Biology) C.E. 59 (Sanitary Engineering)
58—Masonry Structures	Mech. 102 (Analytical Mechanics) Min. 5 (Minerals of Building Stones)
59—Sanitary Engineering	Chem. 81-82 (Industrial Chemistry)
61—Analytical Theory of Trusses	Mech. 102 (Analytical Mechanics)

Subject	Prerequisite
Civil Engineering (*Continued*):	
62—Graphic Statics	Mech. 102 (Analytical Mechanics)
64—Graphic Statics (abridged course)	Mech. 102 (Analytical Mechanics)
71—Surveying (between Third and Fourth Years)	C.E. 51-52 (Theory of Railroad Surveying) C.E. 25 (Surveying)
75—Hydraulics	Mech. 102 (Analytical Mechanics)
76—Hydraulics. (For E.M.) (C.E. 75 abridged)	Mech. 102 (Analytical Mechanics)
77—Hydraulics. (For E.E.)	Mech. 102 (Analytical Mechanics)
78—Hydraulics. (For M.E.)	Mech. 102 (Analytical Mechanics)
85—Foundations	C.E. 58 (Masonry Structures) Geol. 18 (General Geology)
87-88—The Design and Construction of Bridges, Roofs and Buildings. (For Sanitary Engs.)	C.E. 53-54 (Elasticity and Resistance of the Materials of Engineering) C.E. 61 (Analytical Theory of Trusses) C.E. 62 (Graphic Statics)
89-90—Railroad Engineering 94—Design and Construction of Sewers, and River and Harbor Improvements	C.E. 71 (Surveying) C.E. 26 (Surveying) C.E. 75 (Hydraulics)
95—Engineering Contracts and Specifications	
96—Principles of Hygiene, Sanitary Science and Public Health	57a (Statistics and Interpretation of Water Analysis) 57b (Drainage of Marshes and Lowlands)
98—Water-Supply and Irrigation Engineering	C.E. 26 (Surveying)
99-100—Graduation Thesis	C.E. 75 (Hydraulics)
Drafting	
1 or 2—Elements of Mechanical Drafting	
3 or 4—Descriptive Geometry	
5 or 6—Graphics	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
7 or 8—Structural Drafting	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
Economics	
2—Introduction to Economics	
Electrical Engineering	
2—Elements of Dynamo Electric Machinery	Phys. 3-4 (Elements of Electrical Engineering)
4—Electric Distribution (For E.M. Met.E. and C.E.) *Parallel* E.E. 72 (Direct Current Laboratory)	E.E. 2. (Elements of Dynamo Elect. Mach'y) Phys. 5
52—Design of Direct Current Machinery	E.E. 2 (Elements of Dynamo Elect. Mach'y)
54—Design of Alternating Current Machinery *Parallel* Mech. 110 (Th. of Variable Currents) and E.E. 175-176	E.E. 52 (Design of Direct Current Machinery) Mech. 108
72—Direct Current Laboratory *Parallel* E.E. 4 (Electric Distribution)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43 or 44 (Phys. Laboratory)
73—Direct Current Laboratory. (For M.E.) *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43 or 44 (Phys. Laboratory)
75—Alternating Current Laboratory. (For E.M. and M.E.) (Short course)	E.E. 4 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)

Subject	Prerequisite
Electrical Engineering (*Continued*):	
76—Alternating Current Laboratory. (For C.E.)	E.E. 4 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
98—Thesis (Optional) *Parallel* Subjects of Fourth Year	All courses
101—Generator and Motor Practice *Parallel* E.E. 73 *or* 173-174 (Direct Current Laboratory)	E.E. 2 (Elements of Dynamo Elect. Mach'y) and Phys. 5
103—Electric Motors. (For E.E.)	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
103A—Electric Motors. (For M.E.)	E.E. 4 (Electric Distribution) E.E. 73 (Direct Current Laboratory)
104—Electric Distribution	Phys. 5 and E.E. 2 (Elements of Dynamo Elect. Mach'y)
105—Alternating Current Engineering. (For E.E.)	E.E. 104 (Electric Distribution)
105A—Alternating Current Engineering. (For M.E.)	E.E. 4 (Electric Distribution) E.E. 101 (Dynamo and Motor Practice)
106—Electric Plants	E.E. 104 (Electric Distribution)
107-108—Plant Inspection *Parallel course* E.E. 105	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
109-110—Telegraphy and Telephony	E.E. 2 and E.E. 104
112—Electric Railway. (For E.E.)	E.E. 173-174 and E.E. 104
112A—Electric Railway. (For C.E.)	E.E. 72 E.E. 4
173-174—Direct Current Laboratory *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of the Dynamo) Phys. 5 and 43 or 44
175-176—Alternating Current Laboratory *Parallel* Mech. 109 (Theory of Alternators and Transformers), Mech. 110 (Theory of Variable Currents), E.E. 103 (Electric Motors) and 105 A. C. Eng.	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
177—Instrument Laboratory	E.E. 173-174 (Direct Current Laboratory)
Geology	
4—Petrography	Min. 6 (Optical Mineralogy)
5-6—General Geology	Min. 1-2 (Descriptive and Determinative Mineralogy) Parallel course
16—Index Fossils	Geol. 5-6 (General Geology)
18—General Geology	Min. 5 (Minerals of Building Stones)
19—Physiographic and Applied Geology	Geol. 18 (General Geology)
51—Principles of the Formation of Sedimentary Deposits	Geol. 6 (General Geology) *or* Geol. 18 (General Geology)
52—Discussion of Secondary Structural Features	Geol. 6 (General Geology) *or* Geol. 18 (General Geology)
105-106—Economic Geology	Geol. 6 (General Geology)
107-108—Invertebrate Palæontology	Antecedent work in Geology
110—Geological Examinations and Surveys	Geol. 105-106 (Economic Geology)
112—Field Geology	Geol. 6 (General Geology) Geol. 105-106 (Economic Geology) *desirable, not prerequisite*
201-202—Petrology	Geol. 4 (Petrography)
Law	
2—Business Law	
Mathematics	
1 (or 2)—Algebra	Entrance Mathematics
64 (or 67)—Calculus	Math. 3 (Anal. Geometry)
3 (or 4)—Analytical Geometry	Entrance Mathematics
65 (or 68)—Calculus	Math. 3 (Anal. Geometry) and Math. 64 (Calculus)

Subject	Prerequisite
Mechanical Engineering	
11-12—Steam Power Machinery. (For M.E.)	Phys. 3 (Elementary Mechanics and Heat)
13-14—Steam Power Machinery. (Short M.E. 11-12) (For other than M.E.)	Phys. 3 (Elementary Mechanics and Heat)
17-18—Engineering Thermodynamics	M.E. 11-12 (Steam Power Machinery) *or* M.E. 13-14 (Steam Power Machinery) Mech. 102 (Analytical Mechanics)
19-20—Engine Design	M.E. 39-40 (Machine Design) M.E. 11-12 (Steam Power Machinery) M.E. 17-18 (Eng. Thermodynamics)
22—Gas Power	M.E. 19 (Engine Design) M.E. 33 (Standard Tests and Research Methods
25—Steam Power	M.E. 96S (Steam Power Plant Summer Work)
31-32—Standard Tests and Research Methods *Parallel* M.E. 17-18 (Engineering Thermodynamics)	M.E. 11-12 (Steam Power Machinery)
33—Standard Tests and Research Methods (Continuation of M.E. 31-32)	M.E. 31-32 Std. Tests and Research Methods M.E. 96S (Steam Power Plant Summer Work)
35-36—Kinematics of Machinery	Math. 3-4 (Analytical Geometry)
37—Machine Design	Drafting 7
39-40—Machine Design *Parallel* C.E. 53	M. E. 35-36 (Kinematics of Machinery)
41—Machine Design (Short course of M.E. 39-40) *Parallel* C.E. 53	
46—Water Power	
(For M.E.)	M.E. 35-36 (Kinematics of Machinery) M.E. 60 Hydraulic Laboratory C.E. 78 (Hydraulics)
(For C.E.)	M.E. 63 Hydraulic Laboratory C.E. 75 (Hydraulics) M.E. 78 (Kinematics of Machinery)
52—Organization and Management *Parallel* M.E. 68	
53—Steam Turbines. (For M.E.)	M.E. 17-18 (Eng. Thermodynamics) M.E. 31-32 (Standard Tests, etc.)
(For E.E.)	M.E. 17-18 (Eng. Thermodynamics) M.E. 76 (Standard Tests, etc.)
54—Shop Processes	M.E. 94S (Shop and Factory: Summer Work) M.E. 39 (Machine Design)
56—Water Power Installations *Parallel* M.E. 60 (Hydraulic Laboratory)	C.E. 77 (Hydraulics)
59—Empiric Design	Draft. 1 or 2 (Elements of Mechanical Drafting)
60—Hydraulic Laboratory. (For E.E.) *Parallel* (For M.E.) C.E. 78. (Hydraulics)	C.E. 77 (Hydraulics)
62—Refrigerating Machinery *Parallel* M.E. 18 (Eng. Thermodynamics)	M.E. 17 (Eng. Thermodynamics)
63—Hydraulic Laboratory *Parallel* C.E. 75 (Hydraulics)	
64—Air Machinery	M.E. 17 (Eng. Thermodynamics)
66—Elevators and Conveyors	M.E. 39 (Machine Design)
68—Shops and Factories *Parallel* M.E. 52 (Organization and Management)	E.E. 103 (Electric Power)
70—Pumping Machinery *Parallel* C.E. 78 (Hydraulics)	M.E. 17 (Eng. Thermodynamics)
72—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
74—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
76—Standard Tests. (For E.M., Chem.E. and Met.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Eng. Thermodynamics)
(For E.E.)	M.E. 17-18 (Eng. Thermodynamics)

Subject	Prerequisite
Mechanical Engineering (*Continued*):	
77—Standard Tests. (For C.E., Chem.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Eng. Thermodynamics) M.E. 17-18 (Eng. Thermodynamics) M.E. 76 (Standard Tests, etc.)
78—Kinematics	Math. 3-4 (Analytical Geometry)
94S—Shop and Factory Summer Work	Sh.Wk. 1 (Wood Turning and Pattern Making) Sh.Wk. 2 (Molding and Foundry Practice) Sh.Wk. 12 (Forging)
82—Heating and Ventilation	M.E. 17-18 (Eng. Thermodynamics)
96S—Steam Power Plant Summer Work	M. E. 31-32 (Standard Tests, etc.) M.E. 17-18 (Eng. Thermodynamics)

Metallurgy

101—General Metallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
111—Metallurgy of Copper	Met. 101 (General Metallurgy)
118—Metallurgy of Copper. (Advanced Course)	Met. 111 (Metallurgy of Copper)
122—Metallurgy of Lead, Silver, Gold and Zinc	Met. 111 (Metallurgy of Copper)
128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. (Advanced Course)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
131—Metallurgy of Iron and Steel Prerequisite or *Parallel* Met. 101 (General Metallurgy)	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
134—Metallurgy of Iron and Steel	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
138—Metallurgy of Iron and Steel. (Advanced Course)	Met. 131 (Metallurgy of Iron and Steel)
141—Electrometallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
148—Electrometallurgy. (Advanced Course)	Met. 141 (Electrometallurgy)
151—Constitution and Properties of Alloys	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
155-6—Metallography of Iron, Steel and Industrial Alloys	Met. 131 (Met. of Iron and Steel) *or* Met. 134 (Metallurgy of Iron and Steel)
158—Constitution and Properties of Alloys. (Advanced Course)	Met. 151 (Constitution and Properties of Alloys)
72—Metallurgical Laboratory *Parallel* Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)	Met. 111 (Metallurgy of Copper)
171-2—Metallurgical Laboratory	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
175—Metallurgical Investigation *Parallel* Met. 131 (Metallurgy of Iron and Steel, and Met. 141 (Electrometallurgy)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc) Met. 171 (Metallurgical Laboratory)
64S—Summer Course in Ferrous Metallurgy	Met. 101 (General Metallurgy)
66S—Summer Course in Non-ferrous Metallurgy	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
177—Metallurgical Plant Construction	Draft. 7 or 8 (Structural Drafting) C.E. 53 (Elasticity and Resistance of Materials) Met. 64S (Summer Course in Ferrous Metallurgy) Met. 66S (Summer Course in Non-ferrous Metallurgy)

Subject	Prerequisite
Mineralogy	
1-2—Descriptive and Determinative Mineralogy	Entrance Chemistry Entrance Physics
5—The Minerals of Building Stones	Entrance Chemistry Entrance Physics
6—Optical Mineralogy	Min. 5 (Minerals of Building Stones) *or part of* Min. 1-2 (Descriptive and Determinative Mineralogy) *or equivalent*
7-8—Descriptive and Determinative Mineralogy. (Modification of Min. 1)	Entrance Chemistry Entrance Physics
15-16—Mineralogy	Entrance Chemistry Entrance Physics
Mining	
51—Excavation and Tunneling.	Entrance Mathematics Entrance Chemistry Entrance Physics
52—Boring and Shaft Sinking	E.M. 51 (Excavation and Tunneling)
53—Excavation, Tunneling, Boring and Shaft Sinking.) (For C.E.) (Condensation of E.M. 51 and 52)	Entrance Mathematics Entrance Chemistry Entrance Physics
54—Exploration, Development, and Methods of Working. (For E.M. and Met.E.) Prerequisite or *Parallel*	Geol. 105-106 (Economic Geology) E.M. 52 (Excavation and Tunneling)
56—Mine Engineering Prerequisite or *Parallel*	E.M. 71-72 (Mine Plant) C.E. 76 (Hydraulics)
71-72—Mine Plant	C.E. 28 (Surveying) E.M. 54 (Exploration, Development and Methods of Working) M.E. 13-14 (Steam Power Machinery)
73—Mine Constructions. (For E.M. and Met.E.)	Draft. 7 or 8 (Structural Drafting)
75—Design of Mine Plant *Parallel* E.M. 71-72 (Mine Plant)	C.E. 53 (Elasticity and Resistance of Materials)
77-78—Graduating Thesis or Project	All required subjects in Mining
80—Mill Constructions	M.E. 13-14 (Steam Power Machinery)
81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. (For E.M. and Met.E.)	Min. 1 (Descriptive and Determinative Mineralogy) Phys. 3-4 (Elementary Mechanics and General Physics) Mech. 102 (Analytical Mechanics)
82—Ore-Dressing Laboratory. (For E.M. and Met.E.)	E.M. 81 (Ore Dressing, Milling, and the Mechanical Preparation of Coal)
91—Mine Administration. (For E.M. and Met.E.)	E.M. 54 (Exploration, Development and Methods of Working)
94—Mining Law. (For E.M. and Met.E.)	C.E. 27 (Surveying) E.M. 54 (Exploration, Development and Methods of Working)
95—Mining Conference. (Optional)	
58—Summer Class in Mine Surveying	C.E. 27 (Surveying)
59—Summer Course in Practical Mining	M.E. 13-14 (Steam Power Machinery) E.M. 54 (Exploration, Development and Methods of Working)
Physical Education	
A1-A2 B1-B2	Phys. Ed. A1-A2

Subject	Prerequisite
Physics and Mechanics	
Mech. 1—Mechanics: Statics.	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 3-4—General Physics: Mechanics, Wave-motion, Heat and Light	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 5—Electricity	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 43-44—Physical Laboratory *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 105—Physical Measurements *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Mech. 102—Mechanics	Mech. 1 (Mechanics: Statics) Phys. 3 (Mechanics, Wave-Motion, and first part of Heat) Math. 64 and 65 (Differential and Integral Calculus)
Mech. 105—Thermodynamics	Mech. 102 (Mechanics)
Mech. 107-108—Theory of Electricity and Magnetism	Mech. 102 (Mechanics)
Mech. 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits	Mech. 107-108 (Theory of Electricity and Magnetism)
Shop Work	
1—Wood-turning and Pattern Making. (For M.E.)	
2—Molding and Foundry Practice. (For M.E.)	
10S—Machine Work. (For M.E.)	
11—Machine Work. (For M.E.)	
12—Forging. (For M.E.)	
13-14—Machine Work. (For E.E.)	
15—Forging and Foundry Practice. (For C.E.)	
16—Machine Work. (For C.E.)	
18S—Pattern-making. (For Chem.E.)	
Zoology	
7—Sanitary Biology	Bacteriology 101 (Sanitary Bacteriology)

GENERAL INFORMATION REGARDING COLUMBIA UNIVERSITY

Students in the Schools of Mines, Engineering and Chemistry may enjoy every advantage to be derived from the resources of the University. The University occupies thirty-five buildings, and its grounds cover thirty-five acres. The number of officers of instruction in 1910-11 was 761, and of resident students 7,429.

University Library The Library contains about 450,000 bound volumes, catalogued both by authors and by subjects.

It is open each week-day from 8.30 A.M. until 11 P.M. (in summer, 10 P.M.). All students and graduates have free access and may draw books for home use.

Physical Exercise The Gymnasium is open each week-day from 9.00 A.M. to 7 P.M.; and on Mondays, Thursdays, and Saturdays until 10 P.M.

Every student is entitled to a physical examination by the Medical Director and to advice as to the kind and amount of exercise best adapted to his needs. For the Gymnasium fee see page 18.

The main exercising room is 35 feet high, semicircular in shape, and has an area of 16,000 square feet. It is well lighted and well ventilated. Above are the 10-lap running track, rooms for fencing, boxing, and handball, dressing-rooms with 1,804 steel lockers, and 32 shower-baths. Below the exercising room is the semicircular swimming pool, 100 feet by 50, and 4 to 10 feet deep, and shower-, needle-, and tub-baths.

A two-hour course in Physical Education is prescribed for all first and second year undergraduate students, arranged with a view to securing: first, health; second, strength, control, efficiency, and endurance; third, erect carriage.

There are on South Field a practice field for baseball, lacrosse, and football, a quarter mile running track, tennis courts, and the University Boat House is within easy reach.

Employment Committee The Employment Committee endeavors to give students who need it the opportunity to earn enough for partial or complete support, and to extend assistance in other ways. The office of the secretary of the Committee is in Room 312, East Hall. Communications should be addressed to the Committee. Some of the openings available are: private tutoring, translating, addressing, copying of various sorts, teaching in evening schools, stenography. During the year 1909-10 the student earnings reported to the Committee amounted to $166,777.49.

THE GREEN AND UNION THEOLOGICAL SEMINARY FROM QUADRANGLE

Preference is naturally given, in case of a choice of applicants, to those who, as strangers in New York, are not likely to hear of positions through other channels. No prospective student should come to Columbia expecting to depend entirely or even largely upon the assistance of the Committee, and every student should be prepared to meet at least the expenses of the first half-year—say $250.

The chiefs of clinic in the Medical School give advice without charge to students on the lists of the Committee.

There are also Appointment Committees whose duty it is to recommend graduates for teaching or other positions in colleges and universities and to assist competent men to obtain such positions.

Medical Visitor A University Medical Visitor renders medical assistance to students without family physicians in New York for a remuneration to be arranged between himself and individual patients. The medical visitor is Dr. D. S. D. Jessup, office hours 5 to 6 daily, at 542 West 112th Street (telephone, 6382 Morningside).

Residence Halls There are two University dormitories on South Field, with accommodations for 500 men; Hartley Hall, a memorial to the late Marcellus Hartley, and Livingston Hall, named in memory of Robert R. Livingston, of the class of 1765. Each building is 137 feet by 60 and 10 stories high. They have electric light, steam heat, telephones, elevator and shower baths.

The two Halls contain 600 outside rooms, both single and double, which may be rented singly or in suites. The bedrooms average 8 feet by 14.6, and the studies 10 by 14.6. All are 9 feet high. Each bedroom has a clothes-closet and an enamelled basin with hot and cold water, and is provided with heavy oak furniture.

The entrance to each building faces the campus, and leads directly into an assembly room 60 feet square. This room runs up through two stories and has a large open fireplace opposite the entrance.

The weekly charge for a single room ranges from $2.60 to $4.75 for the academic year of thirty-nine weeks. A pamphlet with floor plans and rental charges and containing the Hall Regulations may be had upon application to the Secretary of the University. Rooms will be assigned in the order of receipt of applications, which should be made on a blank provided by the Superintendent of Buildings and Grounds.

University Commons The University Commons (under student management) for the accommodation of the men living in the Residence Halls is conducted upon a system combining *table d'hôte* and *à la carte*. The Commons, which has accommodations for 450 men, is in University Hall, and is open daily from 7.30 A.M. to 7 P.M. There is also a large buffet lunch room.

Other Accommodations Besides the dormitories and the Greek Letter Society club-houses there are many good boarding-houses and apartments near the University, a card-catalogue of which is kept at Earl Hall.

Public Lectures, etc. In addition to the regular courses of instruction, numerous public lectures are given at the University, ordinarily by persons of distinction who are not members of the teaching staff. The University maintains close relations with the other educational and public institutions of the city, and students enjoy unusual privileges at them. Students are also frequently given the opportunity to enjoy important dramatic and musical performances at a considerably reduced cost.

St. Paul's Chapel St. Paul's Chapel, the gift of Olivia Egleston Phelps Stokes and Caroline Phelps Stokes, as a memorial to their parents, is a beautiful cruciform building with 1,050 sittings. Service, at which attendance is voluntary, is held every week-day except Wednesday and Saturday, at noon, the period from 12 to 12.20 being set apart by the University for religious exercises; on Wednesday afternoons at 5.10; and on Sunday afternoons at 4 P.M. There are also frequent organ recitals.

Earl Hall Earl Hall, the home of the religious, philanthropic, and social organizations and interests, is open to all students, without expense, from 8.30 A.M. to 10 P.M. daily, under the management of its Secretary, who is also Secretary of the University Young Men's Christian Association. Provision for the meetings of student organizations is made in the following order: Societies the purpose of which is (1) primarily religious; (2) primarily philanthropic; (3) primarily literary; and (4) miscellaneous student organizations. In 1907-08, 1,117 student meetings were held in Earl Hall. The building is also much used as a general student club house.

Student Organizations The various student organizations, while self-governing, are subject to the following regulations: The schedules of public contests and performances must be approved by the University Committee on Student Organizations; budgets for expenditure are approved and checked by the Comptroller of Student Organizations; the University Committee on Athletics, consisting of three graduates, two students and two University officers, adopt and administer rules of eligibility not involving questions of scholarship and govern participation in inter-collegiate athletics. A pamphlet containing the full regulations, the constitution of the Athletic Association and the constitution of the Board of Student Representatives may be obtained from the Secretary of the University.

The Degree of A.M. A college graduate who completes with marked distinction one of the regular professional courses may be recommended for the degree of Master of Arts if, while pursuing his professional course, he shall have taken additional work, under the Faculty of Pure Science, Philosophy or Political Science, to the extent of a major subject, and have presented a satisfactory essay upon an assigned topic. A detailed statement of the requirements for this degree and also for the Ph.D., with a list of subjects which may be offered, will be found in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science.* See also page 21.

Fellowships For information as to the fourteen University Fellowships, of the annual value of $650 each, and the several endowed fellowships open to qualified candidates for the degree of Master of Arts and Doctor of Philosophy, see the *Announcement of the Faculties of Political Science, Philosophy and Pure Science,* or the University Catalogue.

The three following are of particular interest to students of Mines, Engineering and Chemistry, who are advised to familiarize themselves with the special regulations governing them:

The Tyndall Fellowship for the Encouragement of Research in Physics, endowed by Professor John Tyndall, and of an annual value of $648; the Barnard Fellowship for Encouraging Scientific Research, endowed by the bequest of the late President Barnard, annual value $500; and the Ernest Kempton Adams Research Fellowship, founded by Mr. Edward Dean Adams in memory of his son, Ernest Kempton Adams, annual value $1,250.

Students

In 1910-11 the registration in the Schools of Mines, Engineering and Chemistry is as follows:

First-year class	189
Second-year class	214
Third-year class	161
Fourth-year class	141
Non-matriculated	20
Students from Columbia College	12
Total	737

Of students registered, 96 already held a college or technical degree, representing 37 institutions. In addition there are registered under the Faculty of Pure Science as candidates for the A.M. and Ph.D. degrees 10 students with some branch of Engineering and 56 with Chemistry as a major subject.

ALUMNI ORGANIZATION

The Alumni Association of the Schools of Science of Columbia University includes in its membership graduates of the Schools of Mines, Engineering and Chemistry. Associate membership is open to non-graduates, members of classes that have graduated.

Honorary membership is open to all persons eminent in Science who are or have been connected with any of the Schools of Science of Columbia University.

Its officers for 1910-11 are:

President, Arthur S. Dwight, E.M., '85.
Vice-President, John H. Janeway, E.M., '86.
Treasurer, John S. Douglas, E.E., '90.
Secretary, Ralph E. Mayer, C.E., '79.
Post Office Substation 84, New York City.

Board of Managers

Wm. de L. Benedict, E.M., '74.
H. S. Kissam, Ph.B., '86.
E. Merz, E.M., '92.
G. H. Clark, C.E., '93.
T. O'Connor Sloane, Jr., E.E., '03.
J. F. Thompson, Ph.D., '03.
A. Aigeltinger, E.E., '07.
H. W. Remington, Jr., M.E., '09.

Delegates to Alumni Council

Charles B. Going, Ph.B., '82
George H. Clark, C.E., '93.
Daniel E. Moran, C.E., '84.

A complete list of the Alumni, giving the addresses of each, and in the case of those who are members of the Association, a detailed record of their professional career, is published and may be had on application to the Alumni Secretary, Columbia University.

The Alumni Secretary will also be glad to put prospective students in communication with Alumni in different parts of the country. Such Alumni are often able in a personal interview to furnish information regarding the Schools of Mines, Engineering and Chemistry which inquirers at a distance could obtain in no other way.

General Alumni Organizations

Alumni Council:

John Howard Van Amringe, '60, Chairman
Rudolf Tombo, Jr., '98 A.M., Secretary, Columbia University

Society of the Early Eighties:

James Duane Livingston, '80, President
Girard Romaine, '82, Secretary, 68 Broad Street, New York City

Society of Older Graduates:
John Howard Van Amringe, '60, President
William de L. Benedict, '74 S, Secretary, 43 Cedar Street, New York City.

Society of the Upper Eighties:
Charles H. Mapes, '85, President
Edward L. Dodge, '88 S, Secretary, Columbia University Club, New York City

Local Association Secretaries

Albany—Rev. Roelif H. Brooks, '00 (Vice-President), 80 Lancaster Street, Albany, N. Y.

California—Dr. John C. Spencer, '82, '85 M., Butler Building, San Francisco, Cal.

China—Dr. F. E. Hinckley, '05 Ph.D., clerk, United States Court for China, Shanghai, China.

Colorado—Roger W. Toll, '06, 661 Humboldt Street, Denver, Colo.

Columbia (Missouri)—E. W. Hinton, '91 L., Columbia, Mo.

Connecticut—John D. Irving, '96, Yale University, New Haven Conn.

Cuba—Humberto Fonts, '09 S, Empedrado 59, Havana, Cuba.

District of Columbia—George Oakley Totten, Jr., '91 F. A., 808 Seventeenth Street, N. W., Washington, D. C.

Illinois—Channing Rust Toy, '04, 150 Michigan Boulevard, Chicago, Ill.

Indiana—Professor George H. Danton, '02, Butler College, Indianapolis, Indiana.

Japan—Rev. Kentok Hori, '07 A. M., College of Literature, Imperial University of Tokio, Tokio, Japan.

Kansas City—David M. Proctor, '05 L., 431 Scarritt Building, Kansas City, Mo.

Kentucky—F. A. Busse, '03 S., 800 Third Street, Louisville, Ky.

Louisiana—Leslie Brewer Smith, '05, 1205 State Street, New Orleans, La.

Madison (Wisconsin)—John L. Kind, '06, Ph.D. (President), University of Wisconsin, Madison, Wis.

Mexico—Gustavo Lobo, '98 S, P. O. Box No. 830, Cadena No. 2, Mexico City, Mexico.

Michigan—Dr. Theodore A. McGraw, Jr., '02 M., 73 Cass Street, Detroit, Michigan.

Minnesota—Professor J. B. Miner, '03 Ph.D., University of Minnesota, Minneapolis, Minn.

Nashville—Eugene Tavenner, '01, Peabody College, Nashville, Tenn.

Nebraska—Dr. C. W. Pollard, '99 M., Paxton Block, Omaha, Neb.

New England—Franklin S. Hoyt, '05 A.M., care Houghton Mifflin and Company, 4 Park Street, Boston, Mass.

New Jersey—W. G. Brandley, '08, 164 Market Street, Newark, N. J.

North Carolina—Henry J. Highsmith, T.C., Wake Forest College, Wake Forest, N. C.

Northeastern Pennsylvania—Clarence D. Shrady, '95 S., Allentown, Pa.

Ohio, Northern (Cleveland)—Frederic W. Streibinger, '95 F.A., 1215 New England Building, Cleveland, Ohio.

Ohio, Central (Columbus)—Professor F. P. Graves, '90, Ohio State University, Columbus, Ohio.

Paris—Charles F. Beach, Jr., '81 L., 95 rue des Petits-Champs, Paris, France.

Philadelphia—Stanley Kidder Wilson, '02, Swarthmore, Pennsylvania.

Pittsburg—W. J. Strassburger, '01 F.A., Glassmere, Pa.

St. Louis—William E. Baird, '02 L., Law Department, City Hall, St. Louis, Mo.

Utah—C. H. Doolittle, '85 S, 508 McCornick Building, Salt Lake City, Utah.

Virginia—Jackson Davis, '08 A.M., Board of Examiners, Petersburg, Va.

Washington—Oliver H. P. La Farge, '91 F.A. (President), Bank for Savings, Seattle, Washington.

Western New York—E. Lyman Tilden, '02 L., Mutual Life Building, Buffalo, N. Y.

Wisconsin—H. W. Buemming, '95 F.A., 521 Jackson Street, Milwaukee, Wisconsin.

Yonkers—James F. Prince, '08, 87 N. Broadway, Yonkers, N. Y.

Academic Calendar

1911-1912

1911—July 5, Wednesday. Twelfth Summer Session opens.

August 16, Wednesday. Twelfth Summer Session closes.

September 2, Saturday. Last day for filing applications for entrance examinations.

September 18, Monday. Entrance examinations, and examinations for deficient and debarred students begin.

September 20, Wednesday. Registration begins.

September 26, Tuesday. Registration ceases for students previously matriculated. Later applications received only upon payment of an additional fee of $5.

September 27, Wednesday. First half-year, 158th year, begins.

Registration ceases for students matriculating for the first time. Later applications received only upon payment of an additional fee of $5.

Scholars report to the Registrar.

September 28. Lectures and recitations begin in all courses.

November 7, Tuesday. Election day, holiday.

November 29, Wednesday. University service in St. Paul's Chapel.

November 30, Thursday, to December 2, Saturday, inclusive. Thanksgiving holidays.

December 20, Wednesday, to January 2, 1912, Tuesday, inclusive. Christmas holidays.

1912—January 8, Monday. Last day for filing applications for entrance examinations.

January 15, Monday. Mid-year entrance examinations begin.

January 24, Wednesday. Mid-year examinations begin.

February 6, Tuesday. First half-year ends.

February 7, Wednesday. Second half-year begins. University service in St. Paul's Chapel.

Registration ceases for students entering the second half-year. Later applications received only upon the payment of an additional fee of $5.

Scholars to report to Registrar.

February 12, Monday. Alumni Day.

February 22, Thursday. Washington's Birthday, holiday.

April 4, Thursday, to April 8, Monday, inclusive. Easter holidays.

May 1, Wednesday. Last day for filing applications for scholarships.

May 20, Monday. Final examinations begin.

May 30, Thursday, Memorial Day, holiday.

June 2, Sunday. Baccalaureate service.

June 3, Monday. Class Day.

June 5, Wednesday. Commencement Day.

June 12, Wednesday. Second half-year ends.

June 17, Monday. Entrance examinations begin.

July 8, Monday. Thirteenth Summer Session opens.

August 17, Saturday. Thirteenth Summer Session closes.

September 16, Monday. Entrance examinations, and examinations for deficient and debarred students begin.

September 18, Wednesday. Registration begins.

September 24, Tuesday. Registration ceases for students previously matriculated. Later applications received only upon payment of an additional fee of $5.

September 25, Wednesday. First half-year, 159th year, begins.

Registration ceases for students matriculating for the first time. Later applications received only upon payment of an additional fee of $5.

Scholars to report to Registrar.

2uZmi H. Robert Bacher 1914 S
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Twelfth Series No. 16 May 4, 1912

Columbia University Bulletin of Information

SCHOOLS OF MINES, ENGINEERING AND CHEMISTRY

MINING
METALLURGY
CIVIL ENGINEERING
SANITARY ENGINEERING
ELECTRICAL ENGINEERING
MECHANICAL ENGINEERING
CHEMICAL ENGINEERING
CHEMISTRY

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ANNOUNCEMENT

1912-1913

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Columbia University
Bulletin of Information

(Issued 25 times during the Academic year, monthly in November and December, and weekly between February and June. Entered as second-class matter at the New York, N. Y., Post Office, Dec. 22, 1900, under Act of July 16, 1894.)

These bulletins include:

1. The Report of the President and Treasurer to the Trustees.
2. The Catalogue of the University, issued in December, price 25 cents.
3. The Announcements of the several Colleges, Schools, and Divisions, issued in the Spring, and relating to the work of the next year. These are made as accurate as possible, but the right is reserved to make changes in detail as circumstances require. The current number of any of these Announcements will be sent without charge upon application to the Secretary of the University.

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FACULTY OF APPLIED SCIENCE

Officers of the Faculty

FREDERICK ARTHUR GOETZE, M.Sc....*Dean and Member of the University Council, ex-officio*

HENRY S. MUNROE, E.M., PH.D., SC.D.....*Elected Delegate to the University Council*

ALEXANDER SMITH, PH.D...*Elected Delegate to the University Council*

ADAM LEROY JONES, PH.D.....*Secretary*

Committee on Instruction

DEAN GOETZE (*Chairman*), Professors KEMP, LOVELL, LUCKE, WALKER, WENDELL, WHITAKER and MAYER.

Committee on Admissions

Professors JONES (*Chairman*), MAYER, SLICHTER and WILLIAMS

The Faculty

NICHOLAS MURRAY BUTLER.....*President of the University*

A.B., Columbia, 1882; A.M., 1883; Ph.D., 1884; LL.D., Syracuse, 1898; Tulane, 1901; Johns Hopkins, Princeton, Yale, and University of Pennsylvania, 1902; Chicago, 1903; Manchester and St. Andrew's, 1905; Cambridge, 1907; Williams, 1908; Harvard and Dartmouth, 1909; D.Litt., Oxford, 1905; Officer de la Légion d'Honneur, 1906; Commander, Order of the Red Eagle (Prussia), 1910; Member American Academy of Arts and Letters, 1911.

FREDERICK ARTHUR GOETZE.....*Dean of Faculty*

M.Sc., Columbia, 1905.

HENRY S. MUNROE.....*Professor of Mining*

E.M., Columbia, 1869; Ph.D., 1876; Sc.D., 1904.

ALFRED J. MOSES.....*Professor of Mineralogy*

E.M., Columbia, 1882; Ph.D., 1890.

JAMES FURMAN KEMP.....*Professor of Geology*

A.B., Amherst, 1881; Sc.D., 1906; E.M., Columbia, 1884.

ROBERT PEELE.....*Professor of Mining*

E.M., Columbia, 1883.

WILLIAM HALLOCK.....*Professor of Physics*

A.B., Columbia, 1879; Ph.D., Würzburg, 1881; Phar.D., National College of Pharmacy, 1892.

[1]FRANCIS B. CROCKER.....*Professor of Electrical Engineering*

E.M., Columbia, 1882; Ph.D., 1895.

MICHAEL IDVORSKY PUPIN.....*Professor of Electro-Mechanics*

A.B., Columbia, 1883; Sc.D., 1904; Ph.D., Berlin, 1889.

WILLIAM H. BURR.....*Professor of Civil Engineering*

C.E., Rensselaer Polytechnic, 1872.

THOMAS SCOTT FISKE.....*Professor of Mathematics*

A.B., Columbia, 1885; A.M., 1886; Ph.D., 1888.

HAROLD JACOBY.....*Rutherfurd Professor of Astronomy*

A.B., Columbia, 1885; Ph.D., 1895.

[1]Absent on leave, 1912-13.

HENRY MARION HOWE.....*Professor of Metallurgy*
B.S., Harvard, 1869; A.M., 1872; LL.D., 1905; B.S., Massachusetts Institute of Technology, 1871; LL.D., Lehigh, 1905.

EARL B. LOVELL.....*Professor of Civil Engineering*
C.E., Cornell, 1891.

JAMES MACLAY.....*Professor of Mathematics*
C.E., Columbia, 1888; Ph.D., 1899.

MARSTON TAYLOR BOGERT.....*Professor of Organic Chemistry*
A.B., Columbia, 1890; Ph.B., 1894; LL.D., Clark, 1909.

J. LIVINGSTON RUTGERS MORGAN.....*Professor of Physical Chemistry*
B.S., Rutgers, 1892; A.M. and Ph.D., Leipzig, 1895.

AMADEUS W. GRABAU.....*Professor of Palæontology*
S.B., Massachusetts Institute of Technology, 1896; S.M., Harvard, 1898; S.D., 1900.

RALPH EDWARD MAYER..*Associate Professor of Engineering Draughting*
C.E., Columbia, 1879.

CASSIUS JACKSON KEYSER.....*Adrain Professor of Mathematics*
B.S., Missouri, 1892; A.M., Columbia, 1896; Ph.D., 1901.

GEORGE L. MEYLAN....*Associate Professor of Physical Education and Medical Director of the Gymnasium*
M.D., New York University, 1896; B.S., Harvard, 1902; A.M., Columbia, 1904.

LEA MCILVAINE LUQUER.....*Assistant Professor of Mineralogy*
C.E., Columbia, 1887; Ph.D., 1894.

HENRY CLAPP SHERMAN.....*Professor of Food Chemistry*
B.S., Maryland Agricultural College, 1893; A.M., Columbia, 1896; Ph.D., 1897.

[1]ALBERT P. WILLS.....*Professor of Mathematical Physics*
B.E.E., Tufts, 1894; Ph.D., Clark, 1897.

SAMUEL A. TUCKER.....*Assistant Professor of Electro-Chemistry*
Ph.B., Columbia, 1895.

[2]ADOLPH BLACK.....*Assistant Professor of Civil Engineering*
C.E., Columbia, 1894.

CHARLES EDWARD LUCKE.....*Professor of Mechanical Engineering*
B.S., College of the City of New York, 1895; M.S., New York University, 1899; Ph.D., Columbia, 1902.

WALTER RAUTENSTRAUCH.....*Professor of Mechanical Engineering*
B.S., Missouri, 1902; M.S., Maine, 1903.

WILLIAM CAMPBELL.....*Associate Professor of Metallurgy*
B.Sc., Durham University, 1898; D.Sc., 1905; M.Sc., Royal School of Mines, 1903; Ph.D., Columbia, 1903; A.M., 1905.

EDWARD LAWRENCE KURTZ.....*Assistant Professor of Mining*
E.M., Columbia, 1893.

CARLTON CLARENCE CURTIS.....*Associate Professor of Botany*
A.B.,Syracuse, 1889; Ph.D., 1893; A.M., Columbia, 1892.

S. ALFRED MITCHELL.....*Assistant Professor of Astronomy*
A.M., Queens, 1894; Ph.D., Johns Hopkins, 1898.

ARTHUR L. WALKER.....*Professor of Metallurgy*
E.M., Columbia, 1883.

[1]Absent on leave, second half-year.
[2]Absent on leave, 1912-13.

GEORGE BRAXTON PEGRAM.....*Associate Professor of Physics*
A.B., Trinity College (N. C.), 1895; Ph.D., Columbia, 1903.

BERGEN DAVIS.....*Associate Professor of Physics*
B.S., Rutgers, 1896; A.M., Columbia, 1900; Ph.D., 1901.

ADAM LEROY JONES.....*Chairman of Committee on Undergraduate Admissions and Secretary of the Faculty*
A.B., Williams, 1895; Ph.D., Columbia, 1898.

CHARLES H. BURNSIDE.....*Assistant Professor of Mechanics*
B.S., Columbia, 1898; A.M., 1899.

MORTON ARENDT.....*Assistant Professor of Electrical Engineering*
E.E., Columbia, 1898.

CHARLES P. BERKEY.....*Assistant Professor of Geology*
B.S., Minnesota, 1892; M.S., 1893; Ph.D., 1897.

JOHN HAROLD MORECROFT..*Assistant Professor of Electrical Engineering*
E.E., Syracuse, 1904; B.S., 1907.

W. BENJAMIN FITE.....*Professor of Mathematics*
Ph.B., Cornell, 1892.

HERBERT E. HAWKES.....*Professor of Mathematics*
A.B., Yale, 1896; Ph.D., 1900.

WALTER IRVINE SLICHTER.....*Professor of Electrical Engineering*
E.E., Columbia, 1896.

GEORGE V. WENDELL.....*Professor of Physics*
B.S., Massachusetts Institute of Technology, 1892; Ph.D., Leipzig, 1898.

MILTON C. WHITAKER.....*Professor of Engineering Chemistry*
B.S., Colorado, 1897; M.S., 1899.

J. PAUL JONES WILLIAMS....*Assistant Professor of Civil Engineering*
B.S., Pennsylvania, 1898; M.S., 1899; C.E., 1908.

EVERETT J. HALL.....*Assistant Professor of Assaying*

FLOYD J. METZGER.....*Assistant Professor of Analytical Chemistry*
Ph.B., Buchtel, 1899; Ph.D., Columbia, 1902.

HARRY L. PARR.....*Assistant Professor of Mechanical Engineering*
A.B., Columbia, 1902; Mech.E., 1904.

SAMUEL OSGOOD MILLER.....*Assistant Professor of Drawing*
C.E., Columbia, 1895.

EDWARD F. KERN.....*Assistant Professor of Metallurgy*
B.S., Tennessee, 1897; Ph.D., Columbia, 1901.

HAL T. BEANS.....*Assistant Professor of Chemistry*
B.S., Nebraska, 1899; A.M., 1900; Ph.D., Columbia, 1904.

CHARLES W. THOMAS..*Assistant Professor of Mechanical Engineering*
Mech.E., Stevens Institute, 1884.

ARTHUR H. BLANCHARD.....*Professor of Highway Engineering*
C.E., Brown, 1890; A.M., Columbia, 1902.

THOMAS B. FREAS.....*Assistant Professor of Chemistry and Curator of the Chandler Museum*
A.B., Stamford, 1896; Ph.D., Chicago, 1911.

ALEXANDER SMITH.....*Professor of Chemistry*
B.S., Edinburgh, 1886; Ph.D., Munich, 1889.

THOMAS H. HARRINGTON.....*Assistant Professor of Drawing*
C.E., Columbia, 1889.

Other Officers

EDWIN R. A. SELIGMAN....*McVickar Professor of Political Economy*
A.B., Columbia, 1879; A.M., 1883; Ph.D. and LL.B., 1884; LL.D., 1904.

GEORGE W. KIRCHWEY.....*Kent Professor of Law*
A.B., Yale, 1877; LL.D., Yale, University of Cincinnati, and New York University, 1908.

HENRY ROGERS SEAGER.....*Professor of Political Economy*
Ph.B., Michigan, 1890; Ph.D., Pennsylvania, 1894.

Associates

FREDERICK A. HALSEY.....*Associate in Mechanical Engineering*
B.M.E., Cornell, 1878.

LINCOLN DE GROOT MOSS.....*Associate in Mechanical Engineering*

F. V. D. LONGACRE.....*Associate in Mechanical Engineering*

CHARLES G. SIMPSON.....*Associate in Mechanics*
Ph.B., Cornell College (Iowa), 1895; A.M., 1902.

Instructors

CHARLES C. TROWBRIDGE.....*Instructor in Physics*
B.S., Trinity (Ct.), 1892; M.S., 1903; Sc.D., 1908.

EDWARD K. JUDD.....*Instructor in Mining*
A.B., Williams, 1901; E.M., Columbia, 1904.

LEIGHTON B. MORSE.....*Instructor in Physics*
Ph.B., Iowa College, 1903; Ph.D., Columbia, 1908.

HAROLD W. WEBB.....*Instructor in Physics*
A.B., Columbia, 1905; Ph.D., 1909.

CAVALIER HARGRAVE JOÜET.....*Instructor in Analytical Chemistry*
Ph.B., Columbia, 1882; Ph.D., 1894.

ARTHUR COLON NEISH.....*Instructor in Chemistry*
A.B., Queen's University, 1898; A.M., Columbia, 1900; Ph.D., 1904.

MAURICE A. LAMME.....*Instructor in Mineralogy*
B.S., Montana Agricultural College, 1903; A.M., Columbia, 1904; Ph.D., 1909.

LEWIS P. SICELOFF.....*Instructor in Mathematics*
A.B., Central College, 1900.

OTTO KRESS.....*Instructor in Engineering Chemistry*
B.S., Columbia, 1906; A.M., 1907; Ph.D., 1909.

CHESTER A. DARLING.....*Instructor in Botany*
A.B., Albion, 1904; A.M., 1906; Ph.D., Columbia, 1909.

JOHN M. NELSON.....*Instructor in Organic Chemistry*
B.S., Nebraska, 1901; Ph.D., Columbia, 1907.

HERMON W. FARWELL.....*Instructor in Physics*
A.B., Dartmouth, 1902; A.M., 1906.

HARRY W. REDDICK..... *Instructor in Mathematics*
A.B., Indiana, 1904; A.M., Illinois, 1906; Ph.D., Columbia, 1911.

EDWARD D. THURSTON, JR.....*Instructor in Mechanical Engineering*
A.B., Columbia, 1905; Mech.E., 1907.

FREDERICK W. HEHRE.....*Instructor in Electrical Engineering*
E.E., Columbia, 1908.

WILLIAM C. MOORE.....*Instructor in Chemistry*
B.S., Peabody, 1903.

JAMES S. MACGREGOR.....*Instructor in Civil Engineering*
B.S., Mass. Inst. of Technology, 1902; M.S., 1904.

JAMES KIP FINCH.....*Instructor in Civil Engineering*
C.E., Columbia, 1906.

ARTHUR LOWELL HERRICK.....*Instructor in Mechanical Engineering*
B.S., Dartmouth, 1909; C.E., Wisconsin, 1910.

NELS J. LENNES.....*Instructor in Mathematics*
S.B., Chicago, 1898; S.M., 1903; Ph.D., 1907.

WILLARD L. SEVERINGHAUS.....*Instructor in Physics*
A.B., German Wallace College, 1904; A.M., 1905.

BURTON W. KENDALL.....*Instructor in Experimental Physics*
S.B., Massachusetts Institute of Technology, 1906.

FRANK L. MASON.....*Instructor in Electrical Engineering*
E.E., Columbia, 1909.

JESSE E. BEANS.....*Instructor in Drawing*

HENRY B. DROWNE.....*Instructor in Highway Engineering*
C.E., Brown, 1903.

GORDON H. GRAVES.....*Instructor in Mathematics*
B.S., Earlham, 1905; A.B., Haverford, 1906; A.M., Columbia, 1909.

MORRIS F. WEINRICH.....*Instructor in Physics*
Mech.E., Columbia, 1904; A.M., 1907.

FREDERICK BARRY.....*Instructor in General and Inorganic Chemistry*
Ph.D., Harvard, 1911.

ARTHUR EDGAR.....*Instructor in General and Inorganic Chemistry*
A.C., Lehigh, 1905; M.S., 1906; Ph.D., Mass. Inst. of Technology, 1912.

HARRY LINN FISHER.....*Instructor in Organic Chemistry*
A.B., Williams, 1909; A.M., Columbia, 1910.

ROBERT F. MCCRACKAN.....*Instructor in Food Chemistry*
B.S., So. Carolina Military Academy, 1903; A.M., Columbia, 1910.

FRANK C. SCHROEDER.....*Instructor in Physics*
B.S., Wisconsin, 1907; C.E., 1910.

HERBERT L. WHITTEMORE.....*Instructor in Physics*
B.S., Wisconsin, 1903.

Lecturers

WILLIAM S. DAY.....*Lecturer in Physics*
A.B., Columbia, 1884; Ph.D., Johns Hopkins, 1897.

FRITZ FELIX HAHN.....*Curator in Palæontology*
Ph.D., Ludwig Maximilian University (Munich), 1910.

PREVOST HUBBARD.....*Lecturer in Engineering Chemistry*

Assistants

WILLIAM S. NELMS.....*Assistant in Physics*
A.B., Southwestern, 1903; A.M., 1904.

BERNARD O. DODGE.....*Research Assistant in Botany*
Ph.B., Wisconsin, 1909.

ABRAHAM GROSS.....*Assistant in Analytical Chemistry*
Ph.B., Pittsburgh, 1898; Ph.M., 1900; A.M., Columbia, 1910.

EDWARD N. MILLIKEN.....*Assistant in Chemistry*
B.S., Columbia, 1907; A.M., 1910.

HAROLD PERRINE.....*Assistant in Civil Engineering*
A.B., Columbia, 1908; A.M., 1909.

GEORGE A. SCOTT.....*Assistant in Physics*
B.S., Wisconsin, 1902.

EDGAR ALTENBURG.....*Assistant in Botany*
A.B., Columbia, 1911.

HENRY M. BACH..... *Assistant in Analytical Chemistry*
Chem.E., Columbia, 1911.

JOHN S. BATES.....*Laboratory Assistant in Engineering Chemistry*
A.B., Acadia, 1908; B.Sc., 1909.

CLEMENT S. BRAININ.....*Assistant in Physics*
A.B., Columbia, 1908.

ROBERT W. BRIGGS.....*Assistant in Civil Engineering*
C.E., Columbia, 1911.

EVEREND L. BRUCE.....*Assistant in Mineralogy*
B.Sc., Queen's, 1909; B.A., 1911.

FRANK R. ELDER.....*Assistant in Organic Chemistry*
B.S., Amherst, 1911.

CHARLES R. FETTKE.....*Assistant in Geology*
B.S., Washington State University, 1910; A.M., Columbia, 1911.

JOHN C. FRAZEE.....*Assistant in Physics*
A.B., Coe College, 1904.

FRED D. FROMME.....*Assistant in Botany*
B.S., South Dakota State College, 1911.

PAUL C. HAESELER.....*Laboratory Assistant in Chemistry*
S.B., Chicago, 1911.

FERDINAND F. HINTZE.....*Assistant in Palæontology*
B.S., Utah; M.A., 1911.

FREDERICK R. KELLER.....*Assistant in Electrical Engineering*
E.E., Columbia, 1911.

WALTER W. MCKIRAHAN..*Laboratory Assistant in Physical Chemistry*
A.B., Muskingum College, 1905.

FREDERICK S. NOWLAN.....*Assistant in Mathematics*
A.B., Acadia, 1908; A.M., Harvard, 1909.

GEORGE A. PFEIFFER.....*Assistant in Mathematics*
M.E., Stevens, 1910; A.M., Columbia, 1911.

ALBERT J. SALATHE.....*Laboratory Assistant in Inorganic Chemistry*
A.B., Colgate, 1910.

CARL A. SCHWARZE.....*Assistant in Botany*
B.S., Missouri, 1909; A.M., Columbia, 1911.

WILLIAM W. STIFLER.....*Assistant in Physics*
A.B., Shurtleff, 1902; A.M., Illinois, 1908; Ph.D., 1911.

WILBUR D. TUPPER.....*Assistant in Drawing*
C.E., Columbia, 1911.

WILLIAM HUNT MURPHY.....*Assistant in Physics*
B.S., McGill, 1908.

Non-Resident Lecturers for 1911-1912

ARTHUR S. DWIGHT, E.M. ..... *Roasting Lead Ores*
Consulting Mining Engineer.

H. W. HARDINGS ..... *Tube Mills*
Hardings Conical Mill Co.

GEORGE C. STONE, Chem. ..... *Franklin Furnace*
President, New Jersey Zinc Co.

C. P. PARIN ..... *The Iron and Steel Industry of India*
Consulting Engineer.

ROBERT Y. WILLIAMS, E.M. ..... *U. S. Bureau of Mines*
U. S. Bureau of Mines.

B. B. THAYER ..... *Mining Practice of Butte*
President, Anaconda Copper Mining Co.

J. PARKE CHANNING, E.M. ..... *Mining Practice at Miami*
Consulting Engineer, Miami Copper Co.

WILLIAM Y. WESTERVELT, E.M. ..... *The Ducktown Copper Mines*
Consulting Engineer.

THOMAS H. LEGGETT, E.M. ..... *Surface Prospecting*
Consulting Engineer.

LINCOLN DEGROOT MOSS ..... *Elevating and Conveying*
Consulting Engineer, Robins Conveyor Co.

FREDERICK HALSEY ..... *Shop Processes*
Editor, American Machinist.

F. F. NICKEL ..... *Pumping Machinery*
Engineer, Henry R. Worthington Co.

F. V. D. LONGACRE ..... *Air Machinery*
Engineer, Ingersoll-Rand Co.

C. H. WILSON ..... *Industrial Niagara Falls*
Shredded Wheat Co.

FREDERICK R. HUTTON, Sc.D. ... *Prevention of Accidents in Shop and Factory*
Engineer, Water Department, N. Y. C.

ALLEN D. WOODS ..... *Steering Engines*
Naval Architect.

C. J. MOORE ..... *Automobile Manufacture*
Operating Manager, Packard Motor Car Co.

LOUIS L. PARK .. *Locomotive Building as Field for Mechanical Engineering*

GANO S. DUNN, E.E. ..... *Turin Conference*
Chief Engineer, J. G. White & Co.

F. J. WHITE, E.E. ..... *Rubber Insulation*
The Okonite Co.

DARROW SAGE, E.E. ..... *Power House Operation*
Chief Engineer, Power House of Hudson & Manhattan R. R. Co.

J. L. BURNHAM, E.E. ..... *Rotary Converters*
General Electric Co.

WILLIAM H. DAVIS ..... *Patents*
Patent Attorney.

L. J. LEWINSON, E.E. ..... *Modern Incandescent Lamps*
Electrical Testing Laboratories.

GEORGE F. SEVER, E.E. ..... *Illumination of a large city*
Department of Water Supply, Gas and Electricity.

C. A. BROWNE, Ph.D. ..... *Sugar Production*
Chemist in charge, New York Sugar Trade Laboratory, N. Y. C.

W. D. HORNE, Ph.D. ..... *Sugar Refining*
Chemist, National Sugar Refining Co.

H. C. HUMPHREYS, Ph.D. ..... *Starch and Glucose*
Chemist, Corn Products Refining Co.

C. E. NORTH, M.D. ..... *Sanitary Milk Production and Commercial Pasteurization*
Consulting Sanitarian.

ROBERT SCHWARZ, B.S. Chem. ..... *Fermenting Industries*
Fermentation Expert.

DAVID WESSON, Ph.D. ..... *Cotton seed oil and its products*
Manager, Technical Department, Southern Cotton Oil Co.

ALOIS VON ISAKOVICS ..... *Perfumes and Perfumery*
Prop., Synsfleur Synthetic Laboratory.

ARTHUR H. ELLIOTT ..... *Gas*
Consulting Engineer, Consolidated Gas Co.

MAXIMILIAN TOCH ..... *Paint*
Paint Manufacturer, Toch Bros.

W. P. MASON ..... *Water*
Professor Chemistry and Sanitary Expert, Rensselaer Polytechnic Institute.

H. S. MINER ..... *Rare Earth Industry*
Chief Chemist, Welsbach Co.

ARTHUR D. LITTLE ..... *Paper-making*
Consulting Paper Chemist and President American Chemical Society, 1912.

JOHN A. BENSEL, M.E.
New York State Engineer, Albany, N. Y.

WALTER W. CROSBY, C.E.
Chief Engineer, Maryland State Roads Commission, Baltimore, Md.

A. W. DOW, Ph.B.
Chemical and Consulting Paving Engineer, New York City.

WALTER H. FULWEILER, B.Sc.
Chief Chemist, United Gas Improvement Company, Philadelphia, Pa.

JOHN M. GOODELL, B.Sc. in C.E.
Editor-in-Chief, Engineering Record, New York City.

NELSON P. LEWIS, A.B., C.E.
Chief Engineer, Board of Estimate and Apportionment, New York City.

LOGAN W. PAGE
Director, United States Office of Public Works, Washington, D. C.

HAROLD PARKER
Chairman, Massachusetts Highway Commission, Boston, Mass.

CHARLES P. PRICE
Manager, American Tar Company, Malden, Mass.

H. B. PULLAR
Chief Chemist, American Asphaltum and Rubber Company, Chicago, Ill.

JOHN R. RABLIN
Chief Engineer, Massachusetts Metropolitan Park Commission, Boston, Mass.

CLIFFORD RICHARDSON, A.B.
Consulting Engineer, New York City.
PHILIP P. SHARPLES, A.B.
Chief Chemist, Barrett Manufacturing Company, Boston, Mass.
FRANCIS P. SMITH, Ph.B.
Chemical and Consulting Paving Engineer, New York City.
ALBERT SOMMER, D.Ing.
Consulting Chemist, New York City.
GEORGE W. TILLSON, C.E.
Consulting Engineer, Borough of Brooklyn, New York City.

University Officers of Administration

FRANK DIEHL FACKENTHAL, A.B.....*Secretary of the University*
WILLIAM A. HERVEY, A.M.....*Registrar of the University*
CHARLES S. DANIELSON.....*Bursar*
FRANK A. DICKEY, A.B.....*Assistant Registrar of the University*
HENRY L. NORRIS, M.E.....*Superintendent of Buildings and Grounds*
MALCOLM M. ROY, A.B....*Secretary, Committee on Employment for Students*

Chaplain of the University

REV. RAYMOND C. KNOX, B.D.

Medical Director of the Gymnasium

GEORGE L. MEYLAN, M.D.

Secretary of Earl Hall

JAMES MYERS, A.B.

University Medical Visitor

D. STUART DODGE JESSUP, M.D.

INTRODUCTORY

Columbia University was founded in 1754 as King's College. In 1784, after the Revolutionary War, King's College became, by act of the Legislature of the State of New York, Columbia College. The institution whose name was thus changed has become Columbia University.

The first step for the foundation of a Faculty of Applied Science was taken in 1864, when the Trustees approved the creation of a School of Mines, in which courses were later established in civil engineering, chemistry, and metallurgy. The growth of these courses made it seem desirable to adopt some more comprehensive name than the historic title "School of Mines," so that in 1896 the Schools of Engineering and Chemistry were set off from the School of Mines, the three schools remaining, however, under the jurisdiction of a single faculty:

1. The School of Mines, with four-year courses leading to the degrees of Engineer of Mines and of Metallurgical Engineer.

2. The School of Engineering, with four-year courses in Civil Engineering, Sanitary Engineering, Electrical Engineering, and Mechanical Engineering, leading to the degrees of Civil Engineer, Electrical Engineer, and Mechanical Engineer respectively.

3. The School of Chemistry, with four-year courses, leading to the degrees of Chemist and Chemical Engineer.

The courses are intended to meet the requirements of the several professions indicated; and many of them permit a certain amount of specialization, particularly in the fourth year. The work in the School of Mines is so arranged that the student can emphasize the engineering, the metallurgical, or the geological side of his profession.

Candidates for a professional degree who have some special end in view are occasionally permitted to vary the regular course by substituting other courses offered under the Faculty of Applied Science. Students holding an academic degree may become candidates for the degree of Master of Arts or Doctor of Philosophy (see page 26). Non-matriculated students, properly qualified by age, special training and experience and by ability, may sometimes pursue advanced studies of original research.

In the regular Summer Session held at the University in July and August of each year and in the Department of Extension Teaching many courses of assistance to engineering students are offered. The *Announcement of the Summer Session* and the *Announcement of Extension Teaching* will be sent upon application to the Secretary of the University.

ADMISSION

Until 1914 admission to the Schools of Mines, Engineering and Chemistry will continue to be by examination, and by certificate from

approved degree-granting institutions in so far as the certification corresponds specifically with the stated requirements. *Beginning with 1914 the new requirements described on page* 18 *will go into effect.*

Except for reasons of weight, candidates for admission to the first-year class must be at least eighteen years of age at the time of matriculation, and correspondingly older for admission to advanced standing. Each candidate must before admission present a certificate of good moral character from his last teacher or from some citizen of good standing. Students from other colleges or universities must bring certificates of honorable dismissal. Students are admitted subject to the disciplinary powers of the University authorities.

All requests for information regarding admission should be addressed to the Secretary of the University.

Collegiate Preparation Recommended

For new requirement to go into effect in September, 1914, *see p.* 17.

The liberal training offered by a preliminary Collegiate Course is quite as important to engineers, metallurgists and chemists as to lawyers, physicians or clergymen, and is strongly recommended by the Faculty of Applied Science. This, however, does not and should not involve a residence of eight years in college and technical school before a candidate receives the professional degree.

A graduate of any good college who has selected his course with reference to future work in applied science is able to complete the requirements for a degree in the Schools of Mines, Engineering and Chemistry in less than four years after receiving the Bachelor's degree. The opportunities for close articulation between Columbia College and these Schools are particularly good. Under the provisions of the new program it is possible for a well-prepared student to complete the requirements for both the collegiate and professional degrees in six years.

This six year combined course includes two years College work in English, two years in either French or German and one year each in History and Philosophy, all of these being prescribed for the College degree in addition to the courses included in the professional programs. The necessary total of College credits for the Bachelor's degree is made up by the election of four or more non-technical courses, the exact number depending on the subjects offered for admission. These should include work in Economics and according to the students' own preferences, additional work in English, History, Philosophy or modern languages (Spanish, for example), or work in Latin, Politics, or in some Natural Science not included in the professional program. In general it is better to lay a broad foundation for future professional study than to attempt the anticipation of courses which are later to be dealt with intensively in the professional program.

Under the regulations, a student may either concentrate his collegiate

prescriptions and electives in the first two years of residence and then enter the uniform first year of the professional course, or he may distribute the work of the uniform first year, all of which is non-professional in character, over three years of collegiate residence, and at the beginning of the fourth year, enter the second year of one of the professional courses. The latter plan, which is more likely to insure continuity in the fundamental courses in Mathematics, Physics and Chemistry is, in the judgment of the College Faculty, the more desirable.

Requirements for Admission for Students without Collegiate Preparation

To the First Year Class

Every candidate must offer at the entrance examinations (see below) subjects amounting to fourteen and one-half "units." A unit represents a course of five periods a week for one year in the secondary school.

Total requirement.....14½ units

The candidate must offer:

	Counting in Units
Chemistry	1
Drawing	1
Elementary French *or* Elementary German	2
English	3
Mathematics	3½
Physics	1

and three units from the following:

Elementary French *or* Elementary German *see above*	2
Elementary Spanish	2
Elementary Latin	2
Intermediate French	1
Intermediate German	1
Ancient History	1
Modern and Mediæval History	1
American History	1
English History	1
Botany	1
Physiography	1
Zoölogy	1
Shopwork	1

Candidates for degrees of Engineer of Mines, Metallurgical and Chemical Engineer or Chemist, are recommended to offer Elementary and Intermediate German.

It is suggested that candidates deficient in entrance subjects in June arrange to take courses in them in the Summer Session of

Columbia University, the announcement of which will be sent upon application to the Secretary of the University. Certain of the entrance subjects may also be pursued under the Department of Extension Teaching.

The examination requirements for admission may be satisfied by any one of the three following means, or by any approved combination thereof:

Entrance Examinations

1. By the examinations of the College Entrance Examination Board. These examinations are held annually in June, in 1912 beginning on June 17th, at Columbia University and at about one hundred and fifty other educational centers in the United States and Europe. A complete list of the places and times of such examinations, together with the regulations governing them, may be obtained from the Secretary of the College Entrance Examination Board, Post Office Sub-Station 84, New York City.

2. By the examinations conducted by the Columbia University Committee on Undergraduate Admissions. These examinations are held in September and January of each year (beginning on September 16, 1912, and January 13, 1913), and only at the University.

3. By the examinations of the State Examination Board of the New York State Education Department. These examinations are held in January and June at more than six hundred high schools and other institutions throughout the State of New York, but, save in exceptional circumstances, are open only to students in those schools. Full information regarding the regulations governing them may be obtained by application to the New York State Education Department, Albany, New York.

A copy of the time-scheme of the examinations held by the College Entrance Examination Board in June, and by Columbia University in September and January, together with information as to the proper method of filing application-blanks for these examinations, the payment of fees, the division of examinations, and also detailed definitions of the requirements in each admission subject, is given in the *Bulletin of Entrance Examinations and Admission* for 1912, which may be had upon application to the Secretary of the University.

A candidate may present himself at any of the series of examinations scheduled above, and the results may be credited toward the fulfillment of the requirements for admission, subject to the following restrictions:

Restrictions Governing Examinations

1. A candidate in making application for examination must submit a statement from the principal of his school, or from his last instructor, indicating the extent and character of his preparation in each subject in which he applies for examination, and credit may be withheld when this requirement is not met.

2. The results of an examination may stand to the candidate's credit for twenty-nine months, but no longer.

3. A candidate may not present himself for examination more than four times, except by special consent of the Committee on Undergraduate Admissions.

4. The results of the examinations conducted by the New York State Examination Board can be credited only in so far as the subject-matter of these examinations specifically covers the subjects, or lettered or numbered parts of a subject, which are accepted for admission to the Schools of Mines, Engineering and Chemistry. Candidates who have been granted the College Entrance Diploma issued by the New York State Education Department may be admitted to the Schools of Mines, Engineering and Chemistry free of conditions if the directions given on page 8 of the Columbia University *Bulletin of Entrance Examinations and Admission* have been observed. The diploma should be forwarded to the Secretary of the University together with the application for admission.

5. In order to be credited toward entrance, the reports of a candidate's examinations, together with the statement of the extent and character of his preparation in each subject offered, must be in the hands of the Committee on Undergraduate Admissions one week prior to the opening of the term in September or January.

6. The reports of all examinations must be rendered to the Committee on Undergraduate Admissions in percentages. The Committee interprets these percentages as Passed (P), or Failed (F). Credit toward admission is given only for such examinations as receive a grade of P.

To Advanced Standing

The uniform first year in the Schools of Mines, Engineering and Chemistry, and the efficient coördination of the subsequent years, make it possible for graduates of colleges and scientific schools to enter Columbia University with advanced standing and to complete the requirements for a professional degree without undue delay through conflicts and other causes. It is very desirable, however, that students in other colleges who are planning to take professional work after graduation should get into correspondence with the University as early as possible. If this is done they may receive advice with regard to the most advantageous collegiate subjects to elect, and also with regard to the summer courses of Columbia University. By taking certain summer work at the University in advance, a student sometimes may save six months or a year in entering upon his professional career.

Candidates for admission to advanced standing should make application in writing to the Chairman of the Committee on Undergraduate Admissions in time to reach him on or before September 9, 1912.[1] The application must be accompanied by properly certified official statements of his standing in the subjects which he offers.

[1]When the candidate is at a considerable distance from the University, his application should, if possible, be made earlier than September in order that he may receive the reply in time to present himself at the University on September 16, 1912.

COLUMBIA UNIVERSITY FROM THE WEST

The Committee will notify the candidate at the address given in his letter, between September 9 and 13, 1912, what courses, of those offered, are accepted as equivalent to courses at Columbia University. In general, the Committee gives credit for complete courses only.[1] In cases where the work previously done by the candidate has not been accepted by the Committee, the candidate should present himself at regular fall examinations during the two weeks immediately preceding the opening of the University (in 1912, September 16-23). For courses in which no regular fall examination is held, the candidate should report between 10 A.M. and 12 M. at the Dean's office. The schedule of fall examinations may be obtained from the Registrar.

Admission to Special Courses of Study

Graduates of these Schools, and other institutions of equal grade, may pursue any subjects taught in the schools for which they are qualified.

Persons of mature age who are not graduates, but who show special qualifications, are sometimes permitted to pursue special courses of study, but this permission is not given to others.

Except by vote of the Committee on Undergraduate Admissions no one will be admitted as a non-matriculated student who has been refused admission, or has failed in his work, as a candidate for a degree.

Persons who wish merely to pursue elementary subjects are not received as non-matriculated students.

Non-matriculated students will be held to the observance of the same regulations as to attendance, examination and proficiency as matriculated students.

Admission on Probation

Every first-year student admitted conditionally will be held under probation during the first half-year of residence. So far as possible, students on probation are given the opportunity in Columbia College or in the Department of Extension Teaching, to make good their deficiencies. Not later than the end of this period, the Dean, on the basis of reports from the head of each department in which the student is registered, will decide whether he shall be admitted to full standing, have his period of probation extended, or be dropped from the roll. The mark of 7 or higher, obtained in any subject at the end of the first half-year of residence, will be regarded as removing an entrance condition in that subject, unless the condition was incurred in a part of the subject not directly involved in the work of the course. Any condition not so removed must be satisfied by formal examination.

[1] In cases where credit for part of a course might be given, the candidate should present his case to the Chairman of the Committee on Undergraduate Admissions, at the times given above, bringing drawings, note-books, or other evidence showing the scope and character of his work.

ADVICE TO STUDENTS

Each student is on entrance assigned to an officer of instruction, who acts as his academic adviser. The adviser is kept informed as to the attendance and standing of all such students in their academic work and as to the extent and character of their participation in extra-curricular activities, and he advises students on all these and other matters that concern them as students.

Reports of standing are sent to the student, his parent or guardian, his adviser and to the Dean every five weeks for students in the first and second classes, and at the end of each term for students in the third and fourth classes.

A student who has not been assigned to an adviser may apply to the Dean for such assignment.

NEW REQUIREMENTS FOR ADMISSION

To go into Effect September, 1914

Beginning with the year 1914 the curriculum of the Schools of Mines, Engineering and Chemistry will be reorganized and the requirement for admission will be increased. Three years of specialized work will be offered leading to the several degrees in Engineering and Chemistry. The requirements for admission to these schools will be completion of at least three years of a college course including thorough instruction in Mathematics, Physics, Chemistry, and, in addition, certain courses in Drafting, Shopwork, Surveying and Mineralogy.

The purpose of these changes is to provide better and broader training for students of engineering and to place the instruction in all these subjects upon the same basis as that in Law and Medicine. The rapid development of engineering practice, the wider social recognition attained by the engineering profession and the frequent demand that men in executive and administrative positions shall have an engineering training make it imperative that the engineer shall be a broadly educated, professional man. In order to insure this it is necessary that the future engineer should widen his intellectual outlook by continuing his general education beyond the termination of the high school course. Distinguished engineers among our alumni are sending their sons through college as a preliminary to entering upon professional study. At the present time nearly one hundred students are availing themselves of the opportunity to take the six-year combined college and engineering course in Columbia University.

As a suitable preparation for this advanced work, a new course has been organized in Columbia College, leading to the degree of B.S. Half the student's time is given to thorough sequential work in Mathematics, Physics, Chemistry. Most of the remainder is devoted to courses in English, the Modern Languages, History, Philosophy, and the Political Sciences, and there is some special work in Drafting, Surveying, etc.,

prerequisite to the professional programs. This course is so arranged that a well-prepared student should be able to complete it without undue strain in three years. A student who enters college at the normal age would, therefore, be able to complete the preliminary college course and the three years professional course by the age of 23.

Students who contemplate entering our engineering school and who, for financial, personal, or other reasons, expect to take their college work elsewhere, would do well to consult the Secretary of Columbia University for advice as to the selection and arrangement of their courses with a view to proper articulation between college work and the later professional work. Failure to do this may result in serious loss of time.

REGISTRATION

Before attending any University exercises each student must register, *i. e.*, must present himself in person to furnish the information necessary for the University records and to file a statement of the courses he is authorized to pursue (for the matriculation or registration fee, payable but once, see below).

The office of the Registrar, 201 East Hall, will be open for registration from Wednesday, September 18, to Tuesday, September 24, 1912. New students may register also on September 25. Credit for attendance will date from September 26.

Students prevented, through no fault of their own, from completing their registration in due time, should file a provisional registration-record.

Registration at a later date is permitted only to candidates who obtain the written consent of the Dean, satisfactory cause for the delay having been shown. (For the fee for late registration see below.)

Students holding scholarships are required to register not later than the date specified in the University calendar; failure to do so may be considered as vacating the scholarship.

Honorable Dismissal

In case of withdrawal during the academic year, students are requested to file a notice thereof with the Registrar, on a blank form provided for the purpose. An honorable dismissal is granted by the Dean to any student in good standing over twenty-one who may desire to withdraw, and, with the written assent of his parent or guardian, to a student under that age. Applications for leave of absence should be addressed to the Dean.

FEES

The President is under instructions to withdraw the privileges of any student delinquent in payment after the second Wednesday of each half-year. All regulations as to fees are subject to change by the Trustees at their discretion.

For Matriculation or Registration: Required of all students on entrance, payable but once..... $5

For late Registration (see above)..... 5

For Changes of Registration after the second Saturday of any half-year, for any course or courses added or dropped at any one time..... 1

For Tuition in the Schools of Mines, Engineering and Chemistry, payable at the beginning of each half-year: For matriculated students for each half-year..... 125

For non-matriculated students, $7.50 per half-year for each hour of attendance upon lectures and recitations per week; with additional charges for laboratory work up to $25 per half-year when the number of hours weekly of such work does not exceed nine, and of $40 per half-year when the number of hours weekly exceeds nine; the whole not to exceed $125 per half-year.

For the use of the Gymnasium: Required of all students who do not hold an academic degree; optional for students holding such a degree..... 7

For examinations, payable in each case before the examination:

For entrance (see p. 14 *et seq*)..... 5

For a deficiency examination or series of deficiency examinations held in the week preceding the opening of the first half-year, for each course $5, with a maximum of..... 25

For a deficiency examination at any other time than in the period designated above, whether taken at the conclusion of a course repeated by the student in addition to his normal schedule, or without such repetition, for each course[1]..... 5

For special examinations at unusual times:

For admission, for the series..... 5

For removal of deficiencies in course, for each course..... 5

For any professional degree, payable prior to filing of application[2]..... 25

Summer Courses in Surveying

Laboratory fees, payable on or before the last Saturday in May, are required as follows: Civil Engineering course No. 15, $25, or $7 per survey; No. 25 and No. 27, $15, or $3.50 per survey; No. 26, $5: No. 28 and No. 71, $10.

Non-candidates, candidates for admission to, and students having entered with advanced standing, who may be required to attend these courses, and students who fail to complete them in the summer to which they are assigned, are charged in addition tuition fees as follows: No.

[1] This applies to every course in which the student has already received a mark other than passing, whether such mark was reported as a failure, or merely as incomplete.

[2] Refunded to unsuccessful candidates upon application to the Registrar not later than June 20 next ensuing.

15, $35; No. 25, No. 27, No. 28, and No. 71, $25; No. 26, $10. Students entering with credit for part of course 15 and students deficient in separate surveys of that course shall pay a tuition fee of $10 for each survey. A tuition fee of $6 is required for each survey of courses 25 or 27 taken under similar conditions. In the case of a student registered in Columbia College who has paid an additional fee under the operation of this rule, an equitable credit will be made should he later complete the requirements for a professional degree, provided he has taken the courses at the time prescribed in the curriculum. In the case of a student admitted to advanced standing the additional fee may be refunded in whole or in part, according to regulations which may be learned from the Registrar.

Deposits for Apparatus, Supplies and for Keys to Desks and Lockers

A deposit for the use of lockers, keys, apparatus, material, and the like, ranging from $1 to $40, is required of students in Mines, Engineering and Chemistry. At the end of the academic year each student will be credited with those articles which he returns in good order, and the value of those he has injured or broken will be deducted from his deposit. Details may be obtained from the Bursar.

Residence Halls and University Commons

(See page 121)

Employment Committee

(See page 120)

Comparative Statement of Students' Probable Expenses for the Academic Year

	Low	Average	Liberal
Matriculation	$ 5	$ 5	$ 5
Gymnasium	7	7	7
Tuition	250	250	250
Books	30	45	60 up
Drafting material	2	10	15 "
Chemical apparatus	25	30	40 "
Room (37 weeks)	90	129	180 "
Board (37 weeks)	150	180	205 "
Clothes and laundry	45	100	175 "
College incidentals	2	15	25 "
Other expenses	10	25	75 "
Summer Courses in Surveying			
Laboratory	25	25	25
Travelling	5	5	5 up
Board (5 weeks)	35	35	35 "
	$681	$861	$1102

The expense for summer courses in surveying applies to all curriculums during the first summer only; for Mining and Metallurgical Engineering students during two summers; for Civil and Sanitary Engineers three summers.

RULES GOVERNING STUDENTS

1. A student cannot be a candidate for more than one professional degree at the same time.

2. A candidate for a degree must comply with all requirements in force at the time said degree is conferred.

3. A student will be permitted to substitute one subject for another provided he obtains the consent of the Dean, the heads of departments concerned and the head of the department giving the technical instruction leading to the degree.

4. A student absent from more than one-tenth of the required exercises will be debarred from examination in that subject. No student shall be exempt from this regulation except by action of the Committee on Instruction.

5. After examinations have been held, officers shall send to the Registrar a list of all students who have attended their courses, indicating proficiency by numbers on a scale of 10, a mark below 6 signifying a failure to pass. Reports of standing will be sent to First- and Second-year students every five weeks, and to the Third- and Fourth-year students at the end of each term. Copies of all reports are at the same time sent to the Dean, to the Faculty adviser and, in the case of First- and Second-year students, to the parent or guardian. They will be sent to the parent or guardian of Third- and Fourth-year students only on request.

6. Regular examinations shall be held at the end of the first half-year, and at the end of the second half-year in all subjects offered during those respective periods. An examination may be held at the completion of any subject which does not extend throughout the given half-year.

7. Special examinations for students deficient at regular examinations shall be held during the two weeks in September preceding the opening of the next following academic year; and for members of the fourth class in subjects belonging to that year only, during the first week in May.

Students who have been debarred are excluded from such examinations in accordance with the terms of the following rule:

Any student who shall have been debarred from any midyear or final examination in any subject shall not be allowed to take a deficiency or make-up examination in said subject until he shall have repeated said course in class.

8. Failure to pass a Summer Session course, credit for which would be accepted as equivalent to a regular undergraduate course in the Schools of Mines, Engineering and Chemistry, shall be counted, in case a student registers for said course, as one of the three failures referred to in Rule 10.

9. The fee for special examinations is $5 for each course, which must

be paid when the application is made. For special examinations in the September series the maximum fee is $25.

10. A student failing to pass in any subject at the regular examinations must present himself for special examination as provided under Rule 7.

Failing to pass the second examination, he must repeat the subject with the next class. Failing a third time to pass a satisfactory examination he may be dropped from the roll of the School.

11. Absence from any regular or special examination provided for in Rules 7 and 8 shall count as a failure unless excused by the Dean for reasons of weight.

12. No student having an entrance deficiency shall be permitted to register for any subject of the second, third or fourth year without the written consent of the Dean, and no student shall be permitted to register for any subject the prerequisites for which have not been satisfied by him unless the Dean, for reasons of weight, grants him special permission.

13. Any student who shall have passed a satisfactory examination in Columbia College in any subject forming a part of one of the professional courses in the Schools of Mines, Engineering and Chemistry will not be required to pursue that subject a second time.

14. During vacations following the close of each year, memoirs on assigned subjects must be prepared by the students in the courses of Mining, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, and Chemistry. The time specified for the completion and handing in of memoirs will be as stated in the respective departmental announcements.

A student failing to hand in his memoir, drawings or other summer work at the time specified by the department in which he is registered shall be considered to have failed; to have his work received later, he will be obliged to pay a fee of $5, as for a special examination.

15. By permission of the Dean, and concurrence of the heads of departments concerned, a student may attend subjects not required for his degree, provided such attendance does not interfere with his regular work. He must fulfill all the requirements exacted from regular students in such course.

Application for each special examination, except as provided below, must be filed at the office of the Registrar at least one week before the examination is to be taken, and in September and May at least one week before the first day of the respective examination periods (in 1912-13 not later than Monday, September 9, and Thursday, April 24, respectively). For later application an additional fee of $5 for any examination or series of examinations will be charged. Applications must be made on blanks (one for each course) to be obtained from the Registrar.

During the academic year students will be held responsible for the

receipt of reports and other official communications sent to them at the coat room in University Hall. During the summer vacation they will be held responsible for the receipt of such communications sent to their home address as given on their registration blank for the preceding academic year.

SCHOLARSHIPS

Fifty scholarships of $250 each, payable in semi-annual instalments during the maintenance of a satisfactory grade, are available to students in Mining, Engineering and Chemistry who are in good academic standing, and in need of pecuniary aid. The awards are not based on competitive examinations. Scholars are not exempt from the payment of fees.

Applications for appointment or reappointment should be made on blanks furnished by the Secretary of the University, and filed with him on or before May 1.

As far as possible awards will be made not later than July 1 by the Committee on Scholarships. Scholarships not allotted at this time, or becoming vacant, may be filled by the Committee at its discretion.

In detail these Scholarships are as follows:

Open to students who have been in the University at least one year—7 J. Pierpont Morgan, 7 Cornelius Vanderbilt, 10 D. Willis James, 1 Morris K. Jesup, 1 Samuel D. Babcock, 1 Oswald Ottendorfer.

Open to students of any class—8 Faculty, 15 Special. The Richard Butler scholarship (open to students born in Ohio; for special regulations see University catalogue) has an annual value of $200.

In addition 40 Pulitzer Scholarships, carrying free tuition and a stipend of $250, are open to competition by graduates of the New York City High Schools.

Marcus Daly Scholarship in Mining Engineering

The Marcus Daly Scholarship of the annual value of $1,000, maintained by Mrs. James W. Gerard in memory of her father, is open to that worker or descendant of a worker in the Montana mines who passes the best competitive entrance examinations. The winner holds the same throughout his course in mining engineering and is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science. The next scheduled competition will be in 1915.

Class of '85 Scholarship

The class of '85 scholarship is open to duly registered students in the Schools of Mines, Engineering and Chemistry, and the holder is entitled to receive the net annual income of the class of '85 School of Mines Scholarship Fund of $8,200. The holder is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science.

Industrial Research Fellowship

An Industrial Research Fellowship was established for the year 1911-12 by the American Brake Shoe and Foundry Company of New York, for the investigation and study of materials to improve the tractive force and wearing qualities of brake shoes as used in railroad service. The work is to be carried out in the chemical laboratories of the University and in one of the plants of the American Brake Shoe and Foundry Company in Mahwah, New Jersey.

The fellowship has a value of $2,000, $1,500 of which is for stipend and $500 for the expense of materials and apparatus in connection with the investigation.

MEDALS AND PRIZES

Prize of the New Jersey Alumni Association

A prize of $50 is awarded annually by the New Jersey Alumni Association to the New Jersey student who passes the best entrance examinations to the Schools, with the proviso that before the award the student shall complete satisfactorily one half-year of academic work.

Barnard Medal

A gold medal valued at $200, endowed by President Barnard, is awarded quinquennially (next award, 1915) on the recommendation of the National Academy of Science to the person who within the five years next preceding shall have made such discovery in physical or astronomical science, or such novel application of science to purposes beneficial to the human race as shall be esteemed most worthy of such honor. For details and for a list of previous awards see the Annual Catalogue of the University.

Illig Medals

A bequest of $2,000 by William C. Illig, E.M., '82, provides for the annual award of medals to the student or students in the graduating class of these Schools who shall, in the judgment of the Faculty, have merited the same by commendable proficiency in their regular studies.

Darling Prize

A prize in Mechanical Engineering, the income of $1,000, bequeathed by Edward A. Darling, formerly Superintendent of Buildings and Grounds, is awarded annually to the most faithful and deserving student of the graduating class in mechanical engineering, the recipient to be chosen by members of the graduating class in that Course from among three names to be chosen by the Faculty.

OPPORTUNITIES FOR ADVANCED INSTRUCTION AND RESEARCH

Special attention is called to the opportunities offered through the Faculty of Pure Science to men who have received the Bachelor's degree or its equivalent from any recognized college or scientific school for advanced instruction and research in Mining Engineering, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering and Chemistry, leading to the degrees of A.M. and Ph.D. Any of the subjects mentioned above may be offered as a major or minor for either of these degrees. An outline of the courses in these subjects which may be offered toward the higher degrees by candidates who have completed the necessary prerequisites will be found in this announcement (see pp. 81, 87, 102 and 107 *et seq.*), and the general regulations as to graduate work are printed in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science,* which may be had upon application to the Secretary of the University. Ordinarily, the degree of Master of Arts may be obtained after one year's work in residence and the degree of Doctor of Philosophy after three years, the minimum requirement for the latter degree, however, being two years.

In 1911-12 graduate courses in highway engineering were established. A separately printed pamphlet descriptive of this work may be had on application to the Secretary of the University.

UNIFORM CURRICULUM FOR THE FIRST YEAR

The curriculum for the first year of the four-year courses leading to the degrees of Engineer of Mines, Metallurgical, Civil, Electrical, Mechanical and Chemical Engineer and Chemist is the same in every respect and the student entering the first-year class need not declare which course he will follow until the beginning of the second year, when he will have the advantage of the experience gained during the first year's work, where uncertainty exists respecting inclination or natural bent.

As will be seen in the tabular statement given below, this first year is mainly devoted to a thorough grounding in Mathematics, Physics and Chemistry, the three fundamental subjects which form the indispensable basis for all broad and successful engineering work, not only in the remaining years of the course, but throughout the entire professional career. Specialization begins to some extent in the second year and becomes more marked in the third and fourth years.

The class is arranged in two divisions, Division B completing Engineering Drafting and Descriptive Geometry in the first term, while Division A is completing Qualitative Analysis and General Inorganic Chemistry, the two divisions reversing the operation in the second term. This plan secures greater concentration of work; it facilitates the transfer of students to advanced standing from other institutions; and it enables well-prepared students entering in February and taking advantage of the University Summer Session to catch up with their class by the following autumn.

To secure the most effective individual instruction the class is also divided for quizzes and recitations into six, eight, and in some cases twelve sections.

First Half Year			Hours per week	
See Page			Class	Lab'y
82	Drafting 1	Engineering Drafting	1	14
82	Drafting 3	Descriptive Geometry	3	
89	Mathematics 1	Algebra	2	
89	Mathematics 3	Analytical Geometry	3	
109	Mechanics, 1	Elementary Mechanics	2	
108	Phys. Educ. A	Gymnasium		2
109	Physics 3	Elementary Mechanics, Properties of Matter and Heat	5	
		Total..	16	16
Second Half Year				
76	Civil Eng. 2	Theory of Surveying	2	
67	Chemistry 4	General Inorganic Chemistry	3	
71	Chemistry 62	Qualitative Analysis	4	13
89	Mathematics 64	Calculus	5	
108	Phys. Educ. A	Gymnasium		2
109	Physics 4	Light, Sound ~~Electricity & Magnetism~~	5	
		Total..	19	15

SUMMER WORK: Civil Eng. 15s. Five weeks of surveying practice.

MINING ENGINEERING

General Statement

The instruction in the School of Mines during the first and second years includes fundamental training in mathematics, physics, mechanics, chemistry, mineralogy, and geology, as outlined in the program of studies on pp. 27 and 34. Laboratory instruction in chemistry, assaying, drafting, mineralogy and geology extends through three years.

The engineering, mining, and metallurgical laboratories are equipped to train the student in the making of scientific tests of engineering materials, and working tests of machines and processes of ore treatment, thus preparing him, as far as it is possible in the school, for work that he will be called upon to do as an engineer.

Practical instruction in summer classes in the field is made an important feature of the curriculum. Details of the summer courses in mining, metallurgy, field geology and surveying will be found on pages 31, 32 and 33.

While much time is given to practical training in the laboratories, in the field, and at the mines and metallurgical establishments, care is taken to subordinate this instruction to a high standard of accomplishment in classroom work.

The courses are severe, and should be undertaken only by those who are well prepared physically, mentally, and by previous training to devote themselves earnestly to the work required of them.

Advanced Students and Graduates can choose their subjects and plan of work much more freely than undergraduates. Suggestions as to graduate work will be found on page 112.

Location—Many coal, iron, and other mines, together with quarries and metallurgical works, are easily accessible from New York in from one to four hours by rail. Among these are magnetic iron mines in New York, New Jersey, and Pennsylvania; stone quarries in the same States, and in Connecticut; anthracite and bituminous coal mines, and natural gas and oil wells in Pennsylvania, and zinc mines in New Jersey. New York and the adjacent States produce each year about half the pig-iron and coal, and over fifty per cent. of the total value of the mineral product of the whole country. There are within easy reach of New York City iron blast furnaces and some of the most skilfully designed and managed steel works, rolling mills, steel and iron foundries, copper smelting and refining works, lead-refining works, zinc works, and electrolytic establishments in the world. New York City, moreover, is the headquarters of many corporations operating mines and metallurgical works in this and other countries. Within a radius of one hundred miles may be studied many phases of the best practice in mining and metallurgy in the country. By going a little farther one may reach the bituminous coal fields and the natural gas,

oil and salt regions in one direction, and the pyrite deposits, and granite and marble quarries of New York and New England in the other; while the excursions of the summer class in mining extend as far as the copper, iron, zinc, lead, silver, and gold regions of Michigan, Missouri, Montana, Colorado, California, Arizona and Utah (see page 32).

Building—The six-story School of Mines building, given by Mr. Adolph Lewisohn, is 145 feet long by 57 feet in width. The basement and sub-basement contain the ore-dressing laboratories. On the main floor are the mining and metallurgical museums and lecture rooms. On the second floor are the offices of the department of mining, the mining and metallurgical department libraries, a drafting-room for the design work of the fourth year, and one of the metallurgical laboratories. On the third floor are the offices of the department of metallurgy, the furnace rooms, the chemical laboratory, metallographic laboratory, and the research laboratories of the same department. On the fourth floor are the assay laboratories.

Equipment

Lecture Illustrations—The lectures on mining are illustrated by sets of books aggregating over 300 volumes, and containing 120,000 selected blue prints, each student having the use of books of prints for home study and for reference during the lectures. These illustrations are supplemented by lantern slides or wall diagrams.

Mining Library—The University library contains complete sets of the transactions of all mining, metallurgical, and engineering societies, and of the more important periodical publications on these subjects. There is also a large collection of books on mining, and all new publications of value are added as they appear. In addition, a small departmental library has been created, which is accessible to students at all times.

Mining Museum—The subject of mining is illustrated by collections, as follows: Maps of coal and metal mines of this and other countries. Working drawings, diagrams, and photographs of mine plant, and of mining and dressing machinery. Models of mines and parts of mines, and of mine plant. Mining tools: picks, shovels, hammers, drills, blasting apparatus, lamps, safety-lamps, anemometers and machine drills. Ores and dressing products from typical works in this and other countries. Surveying instruments: geological compasses and clinometers, attraction compasses, dipping needles, hanging compasses and arcs, transits, lamp signals, rods, and apparatus for plumbing and measuring shafts.

Among the more notable exhibits is a large relief model of one of the mines of the Cleveland-Cliffs Iron Mining Co. of Michigan, a similar model of a typical gold mine in Colorado, and a set of three glass models and two relief models of the Copper Queen Mine in Arizona, a

model of the mine workings in the Mahanoy and Shenandoah anthracite coal basins Pennsylvania, a glass model of the mine workings on the Calumet Conglomerate of Houghton County, Michigan, a model of a standard oil-well drilling rig, and a model of the St. Joseph Lead Co.'s dressing works at Bonne Terre, Missouri. There is also a collection of working drawings of mine plant, and a large collection of underground photographs, taken by magnesium light.

Mining Laboratories—These laboratories, occupying seven rooms, include the following:

The Laboratory for Mechanical Assays contains appliances for quantitative work in hand picking, jigging and vanning small samples of ore, and for panning gold-bearing gravel. For small scale working tests there are a number of specially designed laboratory classifiers, jigs and slime tables.

The Crushing and Sampling Laboratory contains machinery for crushing and sampling large and small lots of ore, including gyratory and jaw crushers, rolls, a sample grinder, ball and pebble mills for fine crushing, gyratory screens, automatic samplers, and laboratory crushers, together with sieves, riffle samplers, etc.

The Laboratory for Working Tests contains an air jig, a buddle, a keeve, magnetic and electrostatic separators, and other similar apparatus for working a ton or more of ore at a time.

The Laboratory of Ore-Dressing Machinery contains full-sized machines of standard types. The apparatus now installed includes three Harz jigs of two, three and five compartments; a Hooper vanning jig, a Richards' pulsator jig and two pulsator classifiers, two round tables, concave and convex; a Johnston vanner, a Wilfley table, a Deister slimer, and a Stein-Bilharz belt table. On the floor below are full-sized classifiers, dewatering cones, automatic feeders, and centrifugal pumps for supplying these machines with water and ore for continuous work.

Mining Laboratory Instruction

The work required is designed (1) to illustrate the physical laws and practical conditions affecting the mechanical concentration, separation, and purification of minerals; (2) to instruct the students in the details of quantitative working tests on both small and large scale; (3) to train them in the adjustment and operation of the standard types of concentrating machines, and in testing the efficiency of such machinery in actual operation, and (4) to give opportunity for original research.

The work includes the reduction of a ton or more of ore to laboratory samples, and tests on portions of this ore by handpicking, hand jigging, and mechanical treatment on laboratory jigs, classi-

fiers, and slime tables, to determine the proper method of mill treatment. These tests are controlled by crushing and vanning samples of the products, and reports of the results obtained are made in a systematic manner.

The large concentrators are arranged to be run continuously, for as many hours as may be necessary, using the same ore and the same water again and again. This is accomplished by running the products of the several machines through dewatering cones, from which the mixed material is transferred to the hoppers of automatic feeders. Variable speed pulleys permit any desired adjustment of the driving mechanisms. The water supply is drawn from a constant level tank fed by a centrifugal pump, and is regulated by dial cocks. Other adjustments are equally under control and can be varied at will.

With each of these machines the student makes a series of experiments. These include the adjustment and regulation of the ore supply, of the feed and wash water, of speed, stroke, and other working conditions, to the treatment of different ores and different grades of sand and pulp. In this work the student is taught to recognize the symptoms of irregular working, to diagnose the trouble with the aid of laboratory tests, and to apply the proper remedy. Incidentally he makes tests of capacity and efficiency, taking frequent samples of the ore feed, and of the different products for quantitative examination, and weighs and measures the ore and water supply and products obtained.

Experiments of this kind for purposes of instruction cannot well be made at concentration works in the field. There the machines must work regularly and without interruption, and any interference with the ore feed, water supply, or other adjustments may occasion loss of valuable mineral.

Research Work—The laboratories have facilities for original investigation in the physical laws controlling the mechanical treatment of minerals.

Original researches have recently been undertaken by graduate students in:

Investigation of magnetic fields with reference to ore-concentration; the effect of variations in the speed of crushing machinery on the production of undersized material; the amalgamation of gold ores; an investigation of the laws of jigging.

Summer Courses

Summer Courses in Surveying—About five weeks' work in surveying is required of each class between the first and second years, and eight weeks between the second and third. See pages 44 and 47.

Summer Course in Mine Surveying—One week is spent at a mine in underground surveying. In 1909 and again in 1910 this work was

done at the Orchard Mine, Wharton, N. J.; in 1911, at workings of No. 3 shaft, of Lehigh Valley Coal Co., Hazleton, Pa.

Summer Course in Practical Mining—Six weeks are spent in detailed study of the plant and methods of working at some mine or mines and in excursions to other mines and mining regions. The course includes shaft-sinking, drifting, stoping, timbering, underground haulage, hoisting, mine drainage, ventilation, surface plant, mine buildings, repair shops, houses, etc., water supply, organization, administration, and underground surveying. Arrangements are made at numerous mines, by which the students, singly or in small groups, may do the work described above according to a definite plan and under the general direction of the department.

These summer courses have been in operation since 1877, and have proved themselves an indispensable adjunct to the regular curriculum. They bear the same relation to the study of mining as laboratory work to the study of chemistry or physics, or clinical instruction and hospital practice to the study of medicine.

In 1908, a division of the class, in charge of an instructor, studied at the lead mines of the Federal Lead Co., Flat River, Mo., and the zinc mines of the Joplin district, Mo. The larger part of the class was sent out in separate squads to copper, iron, gold and silver mines in the West, at which arrangements were previously made and the necessary privileges secured. Among these mines were the Wolverine, Michigan; Golden Reward, Mogul and Homestake, South Dakota; Silver Bow and others of Butte, Montana; the properties of the Tennessee Copper Co., and a number of mines in Bisbee, Tombstone, Cananea, Cripple Creek and Leadville. Several members of the class obtained underground work in the Center Star and War Eagle mines, British Columbia, in Butte and elsewhere. The class numbered 40 men.

In 1909 the entire class of 39 students was again distributed in small squads at gold, silver, copper, zinc, lead, coal and iron mines, in Colorado, Utah, Arizona, Idaho, Montana, Michigan, Missouri, Tennessee and Pennsylvania. The time occupied was from 7 to 10 weeks.

In 1910, the class, numbering 43 men, was scattered through 16 States and for the required work visited over 60 mines.

In 1911, the class numbered 40 men, who studied at gold, silver, copper, lead, zinc and coal mines, in 12 different states.

In 1905 and 1906 the non-ferrous summer class in metallurgy visited copper, lead, gold, silver and zinc works in the vicinity of New York City. The work in iron and steel was performed at several iron and steel works in the vicinity of Pittsburg in 1905. In 1907 students in metallurgy visited more than twenty iron and steel plants near Pittsburg. In 1908 and 1909 and 1910 this work was done chiefly in the several districts visited by the squads of mining students.

This work was supplemented in 1910 by organized trips in June and in November to metallurgical plants in the vicinity of New York.

SUMMER COURSES IN GEOLOGY—One week is devoted to practical field geology. The class is instructed in methods of field observation, locating outcrops, measuring dip and strike, keeping notes, etc., afterward constructing maps and geological sections from the observations noted; all under the supervision of the Professor of Geology.

Other Departments

Information as to instruction and the equipment available for students of Mining and Metallurgy in other departments of the University is to be found in this pamphlet as follows:

Chemistry, 63; Civil Engineering and Surveying, 42-44; Electrical Engineering, 52; Geology, 87-89; Mathematics, 89; Mechanical Engineering, 56; Mineralogy, 103; Physics and Mechanics, 109-110; Metallurgy and Assaying, 36.

ENGINEER OF MINES

The four-year course leading to the degree of Engineer of Mines is intended primarily to train men to undertake the development of mineral properties, the design and construction of mine plants, and to manage mines. It is necessarily a broad one, comprising a wide range of studies in pure and applied science, and for this reason is frequently taken by students desiring a general scientific training.

The subjects most emphasized in this course are mining, metallurgy, geology, and engineering. Metallurgy requires knowledge of inorganic and applied chemistry, qualitative and quantitative analysis, and assaying. Geology must carry with it preliminary training in crystallography, mineralogy, and petrography.

Engineering in all its branches needs a fundamental knowledge of mathematics, physics, mechanics, and thermodynamics. The proper design and construction of mining plants involves the study of certain branches of civil engineering, and the many and increasing applications of machinery to mining make it necessary to give much time to the theory and practice of mechanical and electrical engineering.

FIRST YEAR

See page 27

SECOND YEAR

		First Half Year	Hours per week	
See Page			Class	Lab'y
76	Civil Eng. 23	Theory of Railroad Surveying	2	3
82	Drafting 7	Structural Drafting		3
87	Geology 5	General Geology	3	
89	Mathematics 65	Calculus	5	
103	Mineralogy 1	Mineralogy	3	6
108	Phys. Educ. B	Gymnasium		2
109	Physics 5	Electricity	5	
		Total..	18	14
		Second Half Year		
73	Chemistry 66	Quantitative Analysis	3	12
74	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of the Dynamo	2	
87	Geology 6	General Geology	3	
109	Mechanics 102	Analytical Mechanics	5	
103	Mineralogy 2	Mineralogy	3	3
108	Phys. Educ. B	Gymnasium		2
		Total..	19	17

SUMMER WORK: Civil Eng. 27s and 28s, Practical Surveying (eight weeks).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng 53	Resistance of Materials (Testing Lab.)		3
88	Geology 105	Economic Geology	3	
90	Mech. Eng. 13	Steam Power Machinery	3	
102	Metallurgy 81	Assaying	2	9
104	Mining 51	Excavation and Tunneling	3	
		Total..	16	15
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials—problem work		3
78	Civil Eng. 64	Graphic Statics	1	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory		3
87	Geology 4	Petrography (6 hrs. for 2 months)		3
88	Geology 106	Economic Geology	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
97	Mech. Eng. 80	Experimental Mechanical Laboratory	1	3
104	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 mos.)		3
104	Mining 52	Boring & Shaft Sinking	2	
105	Mining 54	Methods of Mining	3	
		Total..	15	18

SUMMER WORK: Field work, Mining, Metallurgy, and Geology (9 weeks).

FOURTH YEAR

		First Half Year		
84	Elect. Eng. 75	Alternating Current Laboratory	1	3
88	Geology 101	Applied Petrography (elective)		
90	Mech. Eng. 17	Technical Thermodynamics	2	
98	Metallurgy 101, 111	Introduction to Metallurgy and Metallurgy of Copper	3	
100	Metallurgy 131, 141	Electro-Metallurgy and Iron and Steel	2	
105	Mining 71	Mine Plant	3	
106	Mining 73	Mine Constructions	1	
106	Mining 75	Design of Mine Plant		12
106	Mining 81	Ore Dressing	4	
107	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
79	Civil Eng. 76	Hydraulics	2	
87	Geology 16	Paleontology (elective)		
88	Geology 110	Geological Surveys	2	
96	Mech. Eng. 74	Gas Power Machinery	2	
101	Metallurgy 72	Metallurgical Laboratory (10 afts)		2
99	Metallurgy 122	Metallurgy of Gold, Silver, etc.	3	
105	Mining 56	Mine Engineering	3	
105	Mining 72	Mine Plant	3	
106	Mining 78	Thesis		12
106	Mining 80	Mill Constructions	1	
107	Mining 82	Ore Dressing (Lab.)—(afts. of 3 weeks)		3
107	Mining 94	Mining Law	2	
		Total.	18	17

METALLURGICAL ENGINEERING

General Statement

The primary aim of the four-year course leading to the degree of Metallurgical Engineer is to train students to take administrative or laboratory positions in metallurgical works. Great stress is laid on the original planning and executing of work, under constant criticism and discussion from the teachers.

The undergraduate instruction consists of (1) class-room work, lectures, conferences, study of text-books; (2) general laboratory work in metallurgy; (3) training in planning and executing original research; (4) summer courses and other visits to industrial metallurgical works.

Much importance is attached to a thorough training in the fundamental subjects, mathematics, chemistry, physics, geology, mineralogy, and engineering, and to the higher branches of engineering, chemistry and important courses in mining engineering, with a view to their applications to metallurgical and like manufacture.

The instruction in metallurgy is based on the most advanced practice in science of to-day and covers the ground from the introductory courses in metallurgy to the special advanced courses in the various branches of the subject.

To graduate and other *advanced students* and properly qualified *practitioners* the department's laboratories are open under generous restrictions.

Location and Equipment

Location. For the advantages of New York and the adjacent states see page 26.

Metallurgical Establishments Accessible. Some of the most instructive and advanced iron, steel, copper, lead, zinc, and electrolytic works in the world are accessible to students for the study of many phases of the best metallurgical practice. See also page 98. The summer classes visit in different years metallurgical establishments in all parts of the country, including the extreme West and South.

Building. The department occupies about half the new School of Mines Building. See page 29.

Collections. There are large and growing collections of lecture diagrams; of models and working drawings of metallurgical furnaces and machinery; of apparatus for lecture demonstration and illustration of metallurgical principles and processes; and a very large collection of metallurgical specimens and suites, with descriptive and explanatory notes. The metal-working shop has power-driven machines for cutting specimens, etc. Most of the furnaces are gas-fired, and those furnaces which are intended for precise work are heated by electric resistance.

Metallurgical Laboratories. Of these there are four. They serve four chief purposes: (1) to give skill in the use of the instruments of precision of the art; (2) to teach the underlying principles of metallurgy and give familiarity with the conditions, especially as to high temperature, under which metallurgical operations must be carried on, and the use of the principal types of furnaces and other metallurgical apparatus, or in short "Analytical metallurgy"; (3) to give some acquaintance with certain industrial metallurgical processes, or what may be called "Applied metallurgy"; and (4) to give advanced students and qualified practitioners the means of making metallurgical and metallographic researches.

The Instruments of Precision. The students acquire skill with the thermo-electric pyrometer, some industrial and some autographic, with the Wanner optical and the Fery radiation pyrometer, besides which they have the opportunity of using the Mesuré and Noel (Ducretet) and the Le Chatelier optical and the Calorimetric one of Siemens. There are ammeters and voltmeters for controlling the electric furnaces; sclerometers for measuring hardness; Fremont and Brinell impact testing machines; a tensile testing machine; a Berthelot calorimeter for testing fuels; and many other instruments.

Non-Ferrous and Electro-Metallurgical Laboratory. A. For wet and dry metallurgy, the extraction, refining, and alloying of the non-ferrous metals, there are ore-roasting furnaces; gas-fired crucible furnaces; assay muffle furnaces; a high temperature forge; cyanide plants; a filter press; amalgamating pans; a chlorinating barrel; ball mills; two desilverization kettles; and pyrometers. B. For electro-metallurgy, the electrical recovery, deposition, refining, and alloying of metals, there are storage batteries; electrolytic refining vats; and electric furnaces of the Moissan arc, Borchers arc and resistance types.

The Iron and Steel Laboratory. Here there are electric and double muffle gas furnaces especially designed for this laboratory, in which many full-sized tensile test bars may simultaneously be heated to any temperature up to 1300° C., with uniformity and precision; gas and direct-fired crucible furnaces; gas forges; many special furnaces; and small power-driven rolls for studying the influence of the conditions of rolling on the properties of metals.

The Metallographic Laboratories, for the microscopic and pyrometric study of metals, mattes, slags, etc., in which every student in metallurgical engineering has to become skillful, has microscopes of the Leitz, Le Chatelier, Swift, Beck, and other types; equipment for illumination and photography; electric resistance furnaces of different types; portable gas furnaces; and pyrometers.

An Analytical Laboratory in which the students apply to their own metallurgical researches the methods of chemical analysis already learned in the Department of Chemistry (p. 70).

The Assay Laboratory. Has for its main equipment thirty-six gas-fired muffle furnaces, with a corresponding number of desks, which are arranged in rows with a furnace facing each desk. There are, also, a sufficient number of coke pot, coal muffle and gasoline furnaces for the student to become familiar with these types. The usual balance, grinding, and cupel rooms are provided.

Supplies. There is a large stock of ores, irons, steels, alloys, refractory materials, fluxes, etc., which may be used for investigations.

The Metallurgical Library, containing about fifteen hundred volumes of metallurgical treatises, text-books, periodicals, etc., is open to all students, and to others properly introduced. Books may be borrowed under suitable restriction.

Metallurgical Laboratory Instruction

In order to become familiar with a wide range of the conditions and principles of metallurgy, the student makes many experiments, each illustrating, testing, or aiming to discover some one or more metallurgical principles or reactions, or the conditions which permit a given reaction to occur. He must, in general, after each experiment enunciate briefly in writing the law to which his results point, or indicate how far those results severally and collectively support or oppose a given proposition.

These experiments relate chiefly to such subjects as the influence of thermal treatment on the properties and microstructure of metals and alloys, especially iron and steel; the determination of melting points and other temperatures; the relation between the composition of slags and their fusibility; the influence of fluxes; the behavior of refractory materials at high temperatures, either alone or in contact with different slags; the temperature limits and the reactions of roasting operations; the influence of various bodies on the reactions which take place in roasting, in the cyanide process, in the chlorination process, and in pan amalgamation; the interaction of carbon and molten oxides, sulphides, silicates, etc., etc.

Summer Courses

Summer Courses in Metallurgy—No. 62s for mining engineers consisting of visits to non-ferrous metallurgical plants for a period of one week.

For metallurgical engineers the summer course lasts six weeks and includes No. 64s, visits to iron and steel metallurgical plants, and 66s, visits to plants for other metals. On these trips, which cover the practice in both the east and the west, the students are instructed in the actual metallurgical operations as carried on in the field. A prominent part of these courses consists of work such as making

written descriptions of the processes, and sketches of the furnaces and other apparatus, with dimensions, usually from the student's own estimate; explaining the principles on which the processes rest, the reasons for the special shapes and sizes of the apparatus, the chief technical difficulties, how they are overcome, and by what tests the processes are controlled; giving the number of men, and, as far as practicable, the consumption of fuel and other materials, the thoroughness of recovery of the metal sought, etc. From an imaginary set of prices and wages the students have to calculate the cost and profit of certain operations.

Summer Courses in Surveying—About thirteen weeks' work in surveying is required of the class between the first and second years. See pages 44 and 45.

Summer Courses in Geology—After the third year at least one week is devoted to practical field geology. For details see page 88.

Metallurgical Excursions—At stated times excursions, open only to students in Metallurgical Engineering, are made to the neighboring foundries, machine shops, mines, and other points of interest. The students attend these excursions in squads of such size that proper individual instruction can be given to each member of the squad.

COURSES LEADING TO THE DEGREE OF METALLURGICAL ENGINEER

This course, which covers four years, is intended for those who expect to follow metallurgical work and become trained metallurgists in any of the branches of the profession. For the first two years much attention is paid to a thorough training in fundamental subjects, especially in mathematics, chemistry, physics, geology, mineralogy, and preliminary courses in engineering. In the third year instruction in metallurgy begins both by lectures and in the laboratories, while courses in engineering, especially mechanical engineering, chemistry, and geology, are also provided for. The fourth year is devoted largely to advanced courses in metallurgy, and great stress is laid on giving, by laboratory work, familiarity with difficult high temperature conditions of metallurgy, skill in microscopy and pyrometry and training in execution and in the interpretation of the results developed. At the same time attention is devoted to the higher branches of engineering and chemistry and to important courses in mining engineering which are considered necessary.

In the summer schools, carefully arranged courses in general surveying, in railroad work, geological field work, and visits to metallurgical works are provided for. In the six weeks' summer courses at metallurgical works, the students are required to carefully study processes, make dimension sketches of furnaces and mills, and by observation and instruction are given a thorough understanding of metallurgical operations as conducted at the present time.

FIRST YEAR

See page 27

SECOND YEAR

See Page			Hours per wee	
	First Half Year		Class	Lab'y
76	Civil Eng. 23	Theory of Railroad Surveying	2	
82	Drafting 7	Structural Drafting		3
87	Geology 5	General Geology		3
89	Mathematics 65	Calculus	3	
103	Mineralogy 7	Mineralogy	5	
108	Phys. Educ. B.	Gymnasium	3	3
109	Physics 5	Electricity		2
109	Physics 43	Physical Laboratory	5	6
		Total..	18	17
	Second Half Year			
73	Chemistry 66	Quantitative Analysis	3	12
74	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of the Dynamo	2	
87	Geology 6	General Geology	3	
109	Mechanics 102	Analytical Mechanics	5	
104	Mineralogy 8	Mineralogy	3	3
108	Phys. Educ. B.	Gymnasium		2
		Total..	19	17

SUMMER COURSES: Surveying Practice 5 weeks (Civil Eng. 27S).
Surveying Practice 3 weeks (Civil Eng. 28S).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	6
88	Geology 105	Economic Geology	3	
90	Mech. Eng. 13	Steam Power Machinery	3	
102	Metallurgy 81	Assaying	2	9
98	Metallurgy 101	Introduction to Metallurgy	1	
99	Metallurgy 111	Metallurgy of Copper	2	
		Total..	16	15
		Second Half Year		
78	Civil Eng. 64	Graphic Statics	1	3
79	Civil Eng. 76	Hydraulics	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
85	Elect. Eng. 104	Electric Distribution	2	
87	Geology 4	Petrography		3
88	Geology 106	Economic Geology	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
95	Mech. Eng. 60	Hydraulic Laboratory		3
99	Metallurgy 122	Metallurgy of Lead, etc.	3	
104	Mineralogy 6	Optical Mineralogy		3
105	Mining 54	Methods of Mining	3	
		Total..	18	15

SUMMER COURSES: Non-ferrous Works Visits 3 weeks (Met. 66S). Iron and Steel Works Visits 3 weeks (Met. 64S). Geology Field Work 1 week (Geol 112S).

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	
84	Elect Eng. 75	Alternating Current Laboratory	1	3
90	Mech. Eng. 17	Technical Thermodynamics	2	
102	Metallurgy 77	Metallurgical Plant Construction		3
100	Metallurgy 131	Metallurgy of Iron and Steel	1	
100	Metallurgy 141	Electrometallurgy	1	
101	Metallurgy 151	Constitution of Alloys	2	
101	Metallurgy 171	Metallurgical Laboratory		9
102	Metallurgy 175	Metallurgical Investigation	1	
106	Mining 73	Mine Constructions	1	
106	Mining 81	Ore Dressing	4	
107	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
71	Chemistry 122	Physical Chemistry	3	
96	Mech. Eng. 72	Gas Power Machinery	2	3
96	Mech. Eng. 76	Experimental Mech. Engineering	1	3
99	Metallurgy 118	Advanced Metallurgy of Copper	1	
100	Metallurgy 128	Advanced Metallurgy of Lead, etc.	1	
100	Metallurgy 138	Advanced Metallurgy of Iron and Steel	1	
100	Metallurgy 148	Advanced Electrometallurgy	1	
101	Metallurgy 158	Advanced Course on Constitution and Property of Alloys	1	
102	Metallurgy 172	Metallurgical Laboratory		6
107	Mining 80	Mill Construction	1	
107	Mining 82	Ore Dressing		3
107	Mining 94	Mining Law	2	
		Total..	14	15

CIVIL ENGINEERING

General Statement

The four-year course leading to the degree of Civil Engineer is designed to afford a thorough analytical training in construction and management. The course contains numerous and extended practical exercises in those matters which pertain to the profession of the civil engineer in relation to all classes of structures and public works and in connection with the various developments and applications of power by the use of steam, electric, water, and air motors. This course is also designed to be an educational preparation for those duties or functions of an executive character whose discharge in connection with the management of public or other works requires, or is rendered more efficient through, a thorough knowledge of civil engineering. The breadth and nature of this educational training adapts it no less efficiently to the purposes of those who intend to follow callings not of an engineering character but which may be related more or less to manufacturing, to structural matters, or to the development and application of power. The theoretical portion of the instruction is based largely upon the courses given in the departments of Mathematics, Mechanics, and Physics, and the results obtained are applied to practical engineering work. Special stress is laid upon the design by the student of the various structures and machines which the civil engineer is called upon to construct or operate in the practice of his profession. The instruction is given by lectures, demonstrations by the student, and frequent conferences, co-ordinate with which the work of design is continuously carried on. It covers comprehensively the subjects of surveying, road and railroad engineering, water supplies of cities and towns, irrigation, sanitary engineering, including sewage disposal, both graphic and analytic treatment of all metallic structures, foundations, retaining and reservoir walls, high masonry dams, sewer systems, hydraulic engineering, rivers and harbors, pumping engines, hydraulic, steam and electric motors.

Ample facilities are afforded for post-graduate students in civil engineering, and special students are admitted to various engineering courses of the department upon evidence of proper qualifications.

Equipment

The school possesses an unusually full equipment of engineers' and solar transits, levels, plane tables, compasses, and all accessories, as well as smaller instruments. Current meters, hook gauges, and floats of

various types are also used in making observations on the flow in, and discharge of, rivers and canals. A complete set of sections of iron and steel shapes, models and photographs of engineering works, together with working plans of the latter, are in the department for the use of students. The hydraulic laboratory affords opportunity for the practical operations of measuring the discharge through weirs and other orifices, the flow through open channels and closed pipes, frictional and other resistances in pipes and open channels, as well as for meter gaugings, and for general hydraulic investigations. The testing work in the mechanical laboratory includes the complete tests of various structural materials in tension, compression, bending, and torsion, including the observation and digesting of all corresponding data.

A cement-testing laboratory is fully equipped with testing machines, briquette molds, tanks, and other apparatus requisite for all classes of investigations in the nature and physical properties of cements and cement mortars.

A complete laboratory for the testing of road materials has been established and is constantly in use for investigations connected with materials suitable for road building. The facilities offered by the laboratory are full and sufficient to make all tests required to determine resistance to abrasion, classification of sand, gravel and broken stone and the cementing power of all qualities of road materials. The laboratory is at the service of students and is used by them, both for the ordinary prosecution of studies to which the determination of results is related and for the purposes of thesis work, and other similar investigations.

The Materials Testing Laboratory is located at the north end of the main floor of the Engineering Building. It is fully equipped with modern appliances for the conduct of tests upon all structural materials. There are seven testing machines varying in capacity from 600 lbs. to 400,000 lbs., representing all American types, including a 150,000-lb. Emery hydraulic power machine, which is a standard of accuracy, and the refinement of mechanical construction. These machines are suited to make tension, compression, transverse and torsion tests upon metals, also to make all desired tests upon building materials, such as timber, stone, brick, concrete blocks or concrete-steel beams, columns, partition blocks, and all built up materials.

The laboratory is also liberally supplied with a large assortment of extensometers, deflectometers, micrometers, gauges, and similar instruments of precision for measurement of test pieces.

Other apparatus, such as delicate scales of different sizes for use in absorption and freezing tests on building materials, also pyrometers and furnaces for the conduct of fire tests upon all kinds of fire-resisting materials are available.

General Statement of the Summer Courses in Surveying and Geodesy at Camp Columbia, Morris, Conn.

The instruction in Surveying given by the Department of Civil Engineering consists of lectures, recitations and problem work, supplemented by instrumental practice in field work, and office work in computation and mapping. The general lectures and recitations are given at the University. The field practice is given during the three summer vacations of the regular four-year course. The subject of Geodesy is given by the Department of Astronomy, and the practical work connected therewith is done under the supervision of that department by students in Civil Engineering during a portion of five weeks of the summer vacation between the third and fourth years. The theory of Plane Surveying, including Railroad Surveying, is given by the Department of Civil Engineering. The field practice is conducted under the direction of the Department at Camp Columbia, a point in the country near Litchfield, Conn., where ample facilities are provided for all requisite operations, and where the topography and climate are admirably adapted to the practical work of surveying. Five weeks' continuous attendance is required of all students in the Schools of Mines, Engineering and Chemistry during the summer between the first and second years. (See C. E. 15, page 76.) Five weeks' additional attendance is required of all students in Civil Engineering (see C. E. 25, page 76), and eight weeks of all students in Metallurgy, and eight weeks of all students in Mining (see C. E. 27 and 28, page 77), during the summer between the second and third years. Nine weeks' continuous attendance is required of all students in Civil Engineering during the summer between the third and fourth years (see C. E. 26, Astronomy 107 and C. E. 71, pages 76, 70, 79). During the summer of 1912 the Summer Courses in Surveying and Geodesy will be in session about fifteen weeks.

No student taking these courses will be excused from any part of any course on account of work done elsewhere, unless that work has been done under the immediate direction of an instructor of an institution which grants degrees in Mining or Civil Engineering. In no case will credit be given except upon the evidence of field-notes, maps, and reports presented to the Professor in charge of the courses.

Two examinations will be held at Camp Columbia and at Columbia University for new students, special students and students who fail to receive a mark of 5.0 (this is not a passing mark in C. E. 2, but entitles the student to take Course C. E. 15) or more in C. E. 2, and this examination must be taken by these men before they begin field work. The first examination will be held July 5 for students who desire to enter with Div. G, and the second one August 9, 1912, for students who desire to enter with Div. I. The University provides

houses or tents having elevated floors, furnished with cots and drafting tables. There are also provided a dining hall and bath house. Arrangements may be made for laundry work to be done in the neighborhood. A supply of drafting materials (not instruments) is kept on sale. Especial attention is given to the wholesome and substantial character of the table.

The cost of board is $6.75 per week and is charged against the individual deposits. The account against each student is reckoned from the day announced for his division to assemble. No allowances or reductions are made for absences of less than one week, and then only in the event of notice having been given and excuse granted by the officer in charge at least one day in advance of the beginning of such absence.

Each student intending to take work in these courses must register with the Registrar of the University not later than May 10. Subsequent changes in plans must be reported at once.

Every student must be present on the day appointed for his division to assemble, unless other arrangements have been made with the officer in charge. Failure to comply with this regulation may be sufficient cause to refuse the applicant's admission to the courses.

Deposits for Camp Expenses

Every student before starting for Camp, and at the same time the fees for the summer session in surveying are paid, shall make a deposit at the Bursar's office at Columbia University to meet Camp expenses, viz., board, laundry, charges for drawing material, notebooks, etc.; also to cover any damage to, breakage, or loss of instruments or Camp equipment, and transportation of self and baggage from the station to and from the Camp. The Bursar's receipt for said deposit shall be presented to the professor in charge of the summer session upon the arrival of the student in Camp.

The amounts of the deposit varies with the course or the number of courses taken and is as specified below. Students intending to take two or more courses shall deposit an amount equal to the sum total of the deposits herein specified for the respective courses. The balance of the deposit which shall remain to the credit of the student after his withdrawal from the session will be returned to him during the following October upon his application to the Bursar of Columbia University. In case the total charges exceed the deposit the student will be subject to an additional assessment.

The deposit for C. E. 15 shall be $50; for C. E. 25, $50; for C. E. 26, $20; for C. E. 27, $50; for C. E. 28, $35; for C. E. 71, $35; and for Geodesy 107, $30.

The deposit for any one *survey* of Course 15, 25, or 27 shall be $15.

FEES.

Laboratory fees, payable on or before the last Saturday in May, are required as follows: Civil Engineering course No. 15, $25, or $7 per survey; No. 25 and No. 27, $15, or $3.50 per survey; No. 26, $5; No. 28 and No. 71, $10.

Non-candidates, candidates for admission to, and students having entered with advanced standing, who may be required to attend these courses, and students who fail to complete them in the summer to which they are assigned are charged in addition tuition fees as follows: No. 15, $35; No. 25, No. 27, No. 28, and No. 71, $25; No. 26, $10. Students entering with credit for part of course 15, and students deficient in separate surveys of that course, shall pay a tuition fee of $10 for each survey. A tuition fee of $6 is required for each survey of courses 25 or 27 taken under similar conditions. (For additional information see page 21.)

Schedule of Attendance

In 1912 the School Session opens June 1 and closes September 14.

Div. A—June 1 to July 6. 5 weeks—Course 25.
Open for all 2d, 3d, 4th year students in Civil Engineering who have completed Course 15.

Div. B—June 1 to July 6. 5 weeks—Course 27.
Open for all 2d, 3d, 4th year students in Mining Engineering and Met. Engineering who have completed Course 15.

Div. C—June 1 to July 6. 5 weeks—Course 15.
Open for all 2d, 3d and 4th year students in the Schools of Mines, Engineering, and Chemistry who have not finished Course 15.

Div. D—June 1 to July 6. 5 weeks—Course 15.
Open for 20 or 25 men of all 1st year students as assigned on basis of scholarship.

Div. E—July 6 to August 10. 5 weeks—Course 25.
Open for 2d, 3d, 4th year students in Civil Engineering who reported with Div. C or Div. D for Course 15.

Div. F—July 6 to August 10. 5 weeks—Course 27.
Open for 2d, 3d, 4th year students in Mining and Metallurgy who reported with Div. C or Div. D for Course 15.

Div. G—July 6 to August 10. 5 weeks—Course 15.
Open for 1st year students as assigned from those not assigned to Div. D and of those who do not register for the summer session in New York. (Probably 75 men.)

Div. H—July 13 to August 17. 5 weeks—Course 26 C. E and Course 107 Astronomy.

For 3d and 4th year students in Civil Engineering who have finished Course 15 and Course 25.

Div. I—August 10 to September 14. 5 weeks—Course 15.

For 1st year students as assigned from those not assigned to Div. D or Div. G. (Special dates may be arranged for those who attend Summer Session at Columbia University in New York.)

Div. J—August 17 to September 14. 4 weeks—Course 71.

For 3d and 4th year students in Civil Engineering who have finished Course 15, Course 25 and Course 51-52.

Div. K—August 17 to September 14. 4 weeks—Part of Course 25 or Course 27.

For 2d, 3d, 4th year students in Mining, Metallurgy and Civil Engineering who reported with Div. C and who withdrew with permission on July 4 to attend Summer Session at Columbia University, in New York.

Div. L—*August 17 to September 14. 4 weeks—Part of Course 15.

For special students not heretofore registered at Columbia University but who have been in attendance at Summer Session at Columbia.

Div. M—August 24 to September 14. 3 weeks—Course 28.

For 2d, 3d, 4th year students in Mining and Metallurgy who have finished Course 15, Course 27 and Course 23.

* Special students wishing to enter this course and who are not in attendance at Summer Session in New York should report August 10.

COURSE LEADING TO THE DEGREE OF CIVIL ENGINEER

FIRST YEAR

See page 27

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
70	Botany 7	Growth and Character of Timbers	1	3
82	Drafting 5	Graphics		3
108	Mathematics 65	Differential and Integral Calculus	5	
89	Mech. Eng. 13	Steam Power Machinery	3	
104	Mineralogy 5	Minerals of Building Stones	2	2
105	Mining 53	Excavation, Tunneling, Boring and Shaft-sinking	2	
108	Phys. Educ. B	Gymnasium		2
109	Physics 5	Electricity	5	
109	Physics 43	Physics Laboratory		3
111	Shop Work 15	Forging and Foundry Practice		3
		Total..	18	16
Second Half Year				
74	Chemistry 82	Industrial	3	
82	Drafting 6	Graphics		3
82	Drafting 8	Structural Drafting		6
83	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	*3
90	Mech. Eng. 14	Steam Power Machinery	3	
109	Mechanics 102	Analytical Mechanics	5	
100	Metallurgy 134	Iron and Steel	2	
108	Phys. Educ. B	Gymnasium		2
109	Physics 44	Physics Laboratory		3
111	Shop Work 16	Machine-work		3
		Total..	18	18

*Saturday P.M., 1 afternoon during April and May—equivalent 1 hour.

SUMMER WORK: Practical Surveying Civil Eng. 25S—5 weeks.

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
70	Astronomy 105	Geodesy	3	
76	Civil Eng. 21	Roads, Streets and Pavements	1	
77	Civil Eng. 51	Railroad Surveying	2	3
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
78	Civil Eng. 59	Sanitary Treatment, Water Supply and Sewage	2	
78	Civil Eng. 61	Theory of Trusses	2	3
90	Mech. Eng. 17	Technical Thermodynamics	2	
97	Mech. Eng. 77	Mechanical Laboratory	1	3
		Total..	18	15
		Second Half Year		
70	Astronomy 106	Geodesy	1	3
77	Civil Eng. 52	Railroad Surveying	3	3
77	Civil Eng. 54	Resistance of Materials (Problems)		3
78	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
90	Mech. Eng. 18	Technical Thermodynamics	2	
97	Mech. Eng. 78	Kinematics	3	
		Total..	17	18

SUMMER WORK: { Hydrographic Surveying—Civil Eng. 26S; Geodetic " —Astronomy 107S } 5 weeks.
Railroad surveying practice—Civil Eng. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
79	Civil Eng. 75	Hydraulics	4	
79	Civil Eng. 85	Foundations	2	3
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	2	
80	Civil Eng. 99	Thesis		3
93	Mech. Eng. 41	Machine Design	1	3
95	Mech. Eng. 63	Hydraulics Laboratory		3
84	Elect. Eng. 75	Alternating Current Laboratory	1	3
	Elect. Eng. 5	Alternating Current Engineering	1	
		Total..	16	18
		Second Half Year		
79	Civil Eng. 88	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 90	Railroad Engineering	3	3
80	Civil Eng. 94	{ Design and Construction of Sewers; River and Harbor Improvement }	2	
80	Civil Eng. 100	Thesis	3	3
85	Elect. Eng. 112	Electric Railway	2	3
89	Law 2	Business Law	2	
93	Mech. Eng. 46	Hydraulic Power Machinery	3	
		Total..	17	12

COURSE IN SANITARY ENGINEERING

The course in Sanitary Engineering is a differentiation from the regular course in Civil Engineering and naturally leads, therefore, to the same degree. The first year is identical with the first year of other engineering courses, while the second year is almost identical with the regular second-year work of the course in Civil Engineering. The special extensions in sanitary work are developed in the third and fourth years. It will be found that these sanitary subjects are set forth so as to cover in a thorough and comprehensive way those special fields occupied by the sanitary engineer of the present day. They include the sanitary treatment of water supplies and sewage with special work extended both by lectures and laboratory work into biology and bacteriology, standard laboratory methods in the sanitary administration of public water supplies, drainage, heating and ventilation and the general principles of sanitary science, public health and hygiene. These sanitary specialties are of advanced character, covering the latest investigations in such special work as daily bacterial tests of potable water for public purposes, the extermination of mosquitoes and other disease-carrying insects, the improvement of public health conditions found in cities and towns, the drainage and sanitary treatment of lands and the sanitary administration of buildings and industrial establishments liable to create nuisances. A graduate, therefore, of this course is qualified to enter the advanced practice of sanitary engineering in all its special fields.

SECOND YEAR

First Half Year			Hours per week	
See Page	Name of Course	Description of Course	Lect.	Lab'y
70	Botany 7	Growth and Character of Timbers	1	3
73	Chemistry 65	Quantitative Analysis	2	6
82	Drafting 5	Graphics		4
89	Math. 65	Differential and Integral Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
104	Mineralogy 5	Minerals of Building Stones	2	2
108	Phys. Educ. B	Gymnasium		2
109	Physics 5	Electricity	5	
		Total..	18	17
Second Half Year				
74	Chemistry 82	Industrial Chemistry	3	
82	Drafting 8	Structural Drafting		2
83	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	3*
109	Mechanics 102	Analytical Mechanics	5	
90	Mech. Eng. 14	Steam Power Machinery	3	
100	Metallurgy 134	Iron and Steel	2	
108	Phys. Educ. B	Gymnasium		2
109	Physics 44	Physics Laboratory		6
111	Shop Work 16	Bench and Machine		3
		Total..	18	14

* April and May—Geology equivalent to 1 hour.
SUMMER WORK: Practical Surveying C.E. 25—5 weeks.

THIRD YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
111	Zoology 7	Sanitary Biology	2	6
70	Bacteriology 101	Sanitary Bacteriology		
76	Civil Eng. 21	Roads, Streets, and Pavements	1	
72	Chemistry 41	Organic Chemistry	2	3
77	Civil Eng. 51	Railroad Surveying	2	3
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials Testing		
78	Civil Eng. 59	Sanitary Treatment of Water Supplies and of Sewage	2	3
78	Civil Eng. 61	Theory of Trusses	2	
		Total..	16	18
		Second Half Year		
72	Chemistry 42	Organic Chemistry	2	
77	Civil Eng. 52	Railroad Surveying	3	3
77	Civil Eng. 54	Resistance of Materials		3
78	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
97	Mech. Eng. 78	Kinematics	3	
		Total..	16	15

SUMMER WORK: Hydrographic Surveying, C. E. 26S—5 weeks.
Railroad Surveying Practice, C. E. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
77	Civil Eng. 55	Physical and Biological Water Analysis		6
77	Civil Eng. 57a	Statistics and Interpretation of Water Analyses	2	
78	Civil Eng. 57b	Drainage of Marshes and Lowlands		
79	Civil Eng. 75	Hydraulics	4	
79	Civil Eng. 85	Foundations	2	
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	2	
90	Mech. Eng. 17	Technical Thermodynamics	2	
95	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	17	15
		Second Half Year		
80	Civil Eng. 90	Railroad Engineering	3	3
80	Civil Eng. 94	Sewers, and River and Harbor Imp.	2	
80	Civil Eng. 96	Principles of Sanitary Science, Public Health and Hygiene	3	
80	Civil Eng. 100	Thesis		6
84	Elect. Eng. 76	Alternating Current Laboratory	1	3
89	Law 2	Business Law	2	
96	Mech. Eng. 76	Mechanical Laboratory	1	3
97	Mech. Eng. 82	Heating and Ventilation	3	
		Total..	15	15

ELECTRICAL ENGINEERING

General Statement

The prescribed course leading to the degree of Electrical Engineer requires four years for its completion, and is designed for the education of those who intend to practice the profession of Electrical Engineering, either as engineers, managers, experts in industrial enterprises or as teachers in colleges or technical schools.

The instruction comprises the important branches of theoretical and applied electricity, also the fundamental and collateral subjects, which have been found by experience to be required by the electrical engineer, as, for example, mathematics, physics, chemistry, drawing, mechanical engineering, including boilers, gas producers, engines, turbines, hydraulic developments, transmission devices and shop work, also such general engineering subjects as construction in wood, masonry, iron and steel.

The graduate in Electrical Engineering is accordingly provided not only with a thorough knowledge of the principles and applications of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for the demands likely to be made upon him in connection with the practice of his profession.

The instruction is by lectures and recitations as well as by laboratory, work-shop and drawing-room practice, with periodic visits to the numerous and important electrical factories, power stations and other establishments in and about New York City.

Equipment

The offices, laboratories, museums and lecture rooms of the Electrical Engineering Department are in the southern portion of the Engineering Building. The laboratories located in the basement contain direct and alternating current machinery and apparatus. The smaller machines are mounted upon heavy tables, thus raising them to a convenient height and affording space for instruments and note-books. To further simplify the work, the machines have been assembled into unit sets, a motor being provided for each generator, so that the experimental work of one squad of students is entirely independent of that of other squads.

The direct current laboratory contains constant potential and constant current generators, motor-dynamos, as well as various types of stationary and railway motors, aggregating fifty machines ranging in capacity from 1 to 35 kilowatts and of standard voltages from 115 to 550. Two 10 and two 5 k.w. generator sets with complete switchboards, carrying many measuring instruments enable various experiments to be performed by the students on the parallel operation of generators.

The constant current equipment includes a dynamo, standard switchboard and series lamp circuits. A working standardization equipment for the calibration of all measuring instruments is installed in this laboratory, and prior to any tests the students are required to check their various instruments. About eighty electrical measuring instruments are employed in this laboratory, comprising ammeters and voltmeters with various scale ranges, also speed indicators, transmission and absorption dynamometers. This laboratory is provided with a set of machine and hand tools employed in the repair of the various pieces of apparatus.

The alternating current apparatus, located in the adjoining room, comprises one single-phase alternator of 10 k.w. capacity and two three-phase alternators of 10 and 45 k.w. capacity, respectively; two 10 kilowatt synchronous motors and rotary converts operative on single-phase or two-phase circuits; two single-phase and four polyphase induction motors varying in capacity from 1 to 10 horse-power; constant potential transformers of various capacities; phase transformers for converting two-phase to three-phase currents and *vice versa;* a constant current transformer equipment of 5 kilowatts capacity with its control board, circuits and lamps; an induction regulator of 5 kilowatts and a mercury arc rectifier of the same capacity. Each of the various alternators is provided with its own driving motor, so that the speed, voltage and frequency may be altered as desired. This laboratory equipment includes a complete switchboard for the operation, control, and testing of the rotary converters used as such or as alternators; also a special polyphase circuit measuring board and about fifty instruments for the measurement of alternating voltage, current and power. The alternating current ammeters and voltmeters are of various capacities, ranging from fractional values up to 2,000 amperes and 600 volts respectively, also wattmeters up to 1,200 kilowatts range. The instrument equipment further includes several frequency indicators, synchronizers and power factor meters as well as a complete oscillograph and an ondograph for the determination of wave forms, phase relations, etc.

The lecture rooms are provided with direct-current, single-phase and polyphase electrical circuits and projection lanterns so that the lectures may be accompanied by experimental demonstrations and illustrations. The museum contains many pieces of apparatus and parts of machines used in connection with the lectures, such as specimens of pole line insulators, conduit material, rail sections, rail bonds, insulated cables and materials employed in transmission line and electric railway construction. Also various pieces of apparatus employed in telegraphy and telephony; forms of storage battery plates, samples of products obtained by electro-chemical actions, elementary electrical apparatus, etc.; pieces of electrical machinery, such as armature laminations, field

and armature coils, commutator sections, brush holders, brushes, insulating materials; small models of various types of generators and motors; numerous forms of incandescent and arc lamps, lamp mechanisms, carbons and electrodes; lightning arresters, line protecting devices and measuring instruments.

On the third floor of the building are located the large instrument laboratory, the departmental drawing-room and the studies of the officers. The laboratory contains tables upon which the various instruments are permanently set up, ready for use. These include many different forms of galvanometers, three ampere balances with scale ranges from .01 to 600 amperes, two dynamometers with ranges of 1 to 200 amperes respectively, a Standard Weston laboratory voltmeter having a range from .01 to 750 volts and a Standard Weston laboratory millivoltmeter with a set of shunts reading up to 500 amperes, Westinghouse precision watt and voltmeters and two very accurate potentiometers. The equipment further comprises apparatus for the exact measurement of resistance, inductance, permeability, hysteresis, and magnetic leakage. This laboratory is supplied with electrical energy from special sources, so that fluctuations do not cause uncertainty in the various measurements. For the direct current work special storage batteries supply potentials up to 250 volts and others have current capacity of 1,000 ampere-hours. For tests requiring small values of alternating currents a special alternator is operated. This laboratory also contains high tension testing apparatus, consisting of two 50,000 volt transformers of 5 and 10 kilowatts capacity respectively, two 10,000 volt transformers of 5 and 10 kilowatts respectively, and one 5,000 volt transformer of 5 kilowatt output. These transformers are supplied with necessary protective and measuring devices and all are designed for operation on 60 cycle circuits. This instrument laboratory is also equipped with several forms of standard integrating and recording watt-hour meters employed in connection with the standardization of consumers' electric meters for the Department of Water Supply, Gas, and Electricity of the City of New York.

The photometric testing laboratory of this Department is situated in the basement of Havemeyer Hall and is equipped with a Lümmer-Brodhun screen photometer for incandescent lamp testing, a Bunsen screen photometer with a meter prover for gas light testing and a Weber photometer, which is adaptable for arc lamp testing or for the determination of general illumination.

COURSE LEADING TO THE DEGREE OF ELECTRICAL ENGINEER

The objects for which the regular four years' course in Electrical Engineering is designed and the education which it is intended to give are fully set forth in the "General Statement" of the Electrical Engineering Department.

The actual curriculum, including the various requirements which must be fulfilled in order to obtain the E. E. degree, are given in the following list of studies for each year, the character of each subject or requirement being explained more fully in the Departmental Statement referred to. The first two years of the course are devoted to the fundamental subjects, including mathematics, physics, chemistry, mechanics, drawing and certain electrical and mechanical engineering subjects which are elementary or introductory in character.

These fundamental and introductory subjects are intended to lay a broad and substantial foundation upon which the more specialized professional instruction of the third and fourth years is based. Even in these later years theoretical subjects, such as thermodynamics and electro-mechanics, are included and given most careful attention.

FIRST YEAR

See page 27

SECOND YEAR

See Page			Hours per week	
	First Half Year		Class	Lab'y
73	Chemistry 65	Quantitative Analysis	2	6
82	Drafting 5	Graphics		3
89	Mathematics 65	Differential and Integral Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
108	Phys. Educ. B	Gymnasium		2
109	Physics 5	Electricity and Magnetism	5	
109	Physics 43	Physical Laboratory		3
109	Physics 105	Physical Measurements	2	
111	Shop Work 13	Machine Work		3
		Total..	17	17
	Second Half Year			
74	Chemistry 82	Industrial Chemistry	3	
82	Drafting 6	Graphics		3
82	Drafting 8	Structural and Machine Drawing		6
83	Elect. Eng. 2	Elements of Dynamo Electric Mach'y	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
109	Mechanics 102	Analytical Mechanics	5	
100	Metallurgy 134	Metallurgy of Iron and Steel	2	
108	Phys. Educ. B	Gymnasium		2
109	Physics 44	Physical Laboratory		3
111	Shop Work 14	Machine Work		3
		Total..	16	17
	Summer memoir.			

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 77	Hydraulics	2	
84	Elect. Eng. 101	Generator and Motor Practice	3	
86	Elect. Eng. 173	Direct Current Laboratory		6
90	Mech. Eng. 17	Technical Thermodynamics	2	
93	Mech. Eng. 41	Machine Design	1	3
109	Mechanics 105	Thermodynamics	2	
110	Mechanics 107	Theory of Generators and Motor	2	
		Total..	17	15
		Second Half Year		
82	Economics 2	Economics	3	
83	Elect. Eng. 52	Design of Direct Current Machinery	2	3
85	Elect. Eng. 104	Electrical Distribution	3	
86	Elect. Eng. 174	Direct Current Laboratory		6
90	Mech. Eng. 18	Technical Thermodynamics	2	
92	Mech. Eng. 36	Kinematics of Machinery		6
96	Mech. Eng. 76	Experimental Mech. Eng.	1	3
110	Mechanics 108	Theory of Dynamo and Motor	3	
		Total..	14	18
		Summer memoir.		

FOURTH YEAR

		First Half Year		
75	Chemistry 183	Electrochemistry	2	3
84	Elect. Eng. 103	Electric Motors	3	
85	Elect. Eng. 105	Alternating Current Engineering	3	
85	Elect. Eng. 109	Telegraphy	1	
86	Elect. Eng. 175	Alternating Current Lab.	1	6
86	Elect. Eng. 177	Instrument Laboratory	1	6
93	Mech. Eng. 53	Steam Turbines	2	
97	Mech. Eng. 77	Experimental Mechanical Laboratory	1	3
110	Mechanics 109	Theory of Alternators & Transformers	4	
		Total.	18	18
		Second Half Year		
83	Elect. Eng. 54	Design of Alt. Current Machinery	2	3
84	Elect. Eng. 98	Graduation Thesis (Optional)		
85	Elect. Eng. 106	Electric Plants	2	
85	Elect. Eng 108	Plant Inspection	1	3
85	Elect. Eng. 110	Telephone	1	
85	Elect. Eng. 112	Electric Railways	2	
86	Elect. Eng. 176	Alternating Current Laboratory	1	8
94	Mech. Eng. 56	Water Power Installations	1	
95	Mech. Eng. 60	Hydraulic Laboratory		3
96	Mech. Eng. 72	Gas Power Machinery	2	3
110	Mechanics 110	Theory of Variable Currents	3	
110	Physics 52	Discharge Electricity	1	
		Total..	15	20

MECHANICAL ENGINEERING

General Statement

The regular four-year course, leading to the degree of Mechanical Engineer, offers a thorough basic training in the design, construction, manufacture and operation of all classes of standard and special machinery, and their economic application to railroads, ships, mills, shops, factories and power plants, as well as in the technical and executive management of the manufacturing and transportation industries. To this end the course of instruction is as broad as is consistent with the directness of its purpose. The Mechanical Engineer must not only be grounded in the fundamental scientific basis of his profession, and so trained as to be capable of applying this to both the technical and commercial aspects of industrial problems, but his immediate usefulness upon graduation demands that a considerable portion of the instruction be concerned with the practical application of the principles taught.

The course begins with a thorough training in mathematics, physics and chemistry as a foundation for the appropriate technical work, which is developed along several parallel lines. Applications of these fundamental sciences to the physical properties of the materials of construction, especially the metals and their practical manipulation, lead through the courses in metallurgy, mechanics, resistance of materials, shop processes, the materials testing laboratory, drafting and kinematics to the principles of design, which are fixed by application to the design of machinery for the execution of any sort of process in which machinery is either absolutely essential or more economical than corresponding hand execution of the same process. The principles underlying the performance of machinery are developed by courses in thermodynamics, mechanics and hydraulics with experimental laboratory demonstration and are fixed by analysis of machinery for steam, gas and water power, pumping, compressing, refrigerating, mechanical handling of materials and their most important applications. The instruction in the performance, design and manufacture of machines and power units in the class-room and laboratory, supplemented by visits to power plants and factories, is the basis of the work on the design of plants and mills.

Throughout the instruction the student is thrown as much as possible on his own resources, encouraged to use such knowledge as he possesses, to read standard authorities and to make comparisons between the existing data on various subjects and with the results of theoretical computations. In the experimental work special stress is laid upon this as a means for the development of that initiative, execu-

tive ability and spirit of investigation so necessary for the successful practice of the profession, which is one long series of new problems demanding solution. The commercial and industrial phases of the technical subjects are dwelt upon throughout the entire course of instruction, and particular attention is given to labor and cost systems, works management, economy of manufacture and of power generation, economics and industrial law.

To insure a close contact between the work of the department and the practice of the profession, recognized experts are invited to give lectures on their particular subjects, the regular officers of the department attending and subsequently holding recitations and examinations.

For a list of special lecturers and their subjects see page 9.

In addition to these regular lecturers, a list of non-resident lecturers, who deliver one or more lectures to the students on the work in their respective engineering fields will be found on pages 9, 10 and 11.

The overlapping of the Mechanical Engineering and Electrical Engineering professions makes it desirable that the Mechanical Engineer shall be thoroughly conversant with the ordinary problems of the Electrical Engineer in the generation and distribution of electric current, the characteristics of electrical machinery, and the design and installation of electrical plants. To this end students in this course receive instruction in the department of Electrical Engineering covering these subjects.

Graduate work in Mechanical Engineering is offered to students who have successfully completed the undergraduate course. This graduate work includes the more difficult applications of mechanics and thermodynamics to questions of engineering, as well as special investigations in design, experimental research, and the development of new processes of manufacture. Courses are also offered to students in other departments covering such instruction in Mechanical Engineering as may properly assist in the practice of their respective professions.

Equipment

Besides the usual offices, lecture rooms, drawing rooms and museum, the department is unusually well equipped with experimental laboratory facilities. These laboratories cover a floor space of some 18,500 sq. ft. and contain apparatus valued roughly at $75,000. A fairly full line of instruments for making simple measurements is always available for regular student work, and includes thermometers, pyrometers, barometers, simple and differential manometers, draft gauges, speed counters, tachometers, angular velocity meters, planimeters, Pitot tubes, water meters of piston, rotary and Venturi type, hook gauges, steam and gas meters, steam, gas, coal and oil calorimeters, flue gas analysis apparatus,

scales for weighing and measuring, transmission dynamometers, Prony brakes, indicators of all types, pressure and vacuum gauges, anemometers, mercury columns, and calibrating apparatus for all instruments. Besides these measuring devices there is a large number of pieces of special apparatus for various purposes, such as the testing of carburetors, pressures due to explosion of gas mixtures, rate of flame propagation in explosive mixtures, pressure and temperatures of vaporization of liquid fuels, loss of head in steam, air and water pipes, condensation of steam in pipes, flow of steam or water through orifices and turbine nozzles, capacity of steam traps, flash, chill, density, viscosity and carbonization of oils, friction of bearings, losses in power transmission. These various instruments and pieces of apparatus are grouped and used in connection with a considerable number of machines of standard form. They include a standard gauge Vauclain compound locomotive, mounted on friction wheels equipped with dynamometers. This locomotive is so erected that it can be operated with its own steam, line steam or compressed air, the exhaust passing through an induced draft fan separately driven by a small steam engine. A Reynolds Allis-Corliss triple expansion engine, double eccentric type, is equipped to operate condensing and non-condensing, and is fitted with reheating receivers and may be operated with line steam or high pressure steam from the locomotive boiler. The Corliss engine has a tandem connected to three air cylinders, equipped with Gutermuth flap valves, operating three-stage with water intercoolers. A cross compound steam, two-stage air compressor of the Ingersoll-Sargent type operates in parallel with the other air compressor and with a Westinghouse simple air pump with complete air brake equipment. There is also a belt and a steam driven fan for fan investigations, together with belt and steam driven centrifugal pumps for corresponding investigation on centrifugal action of water. Besides the steam engines mentioned there are also a Westinghouse two-cylinder, single-acting; McIntosh and Seymour automatic; Sweet straight-line simple engine, besides some smaller reciprocating units, and a De Laval steam turbine, all piped to condensers for efficiency tests on wet, dry or superheated by a Foster superheater separately fired. The steam used by the engines and pumps is measured by any one of three surface condensers, Wheeler, Worthington, Allis, each with its own air and circulating pumps. The steam equipment includes also typical injectors, steam traps, feed water heaters, separators, reducing valves, safety valves, back pressure valves and other ordinary steam auxiliaries and specialties. The hydraulic work is well provided for by two large 20,000-lb. measuring tanks, fitted with swinging guide-bucket for continuous flow measurements, receiving the discharge from all the hydraulic apparatus; water channels of rectangular, trapezoidal and triangular cross section, rectangular and trapezoidal weirs, fitted to

several weir tanks, of iron and wood, three impulse water wheels, one small turbine, hydraulic rams, simple, single and duplex steam pumps, direct acting and flywheel, compound Blake pump, single acting, direct acting triple expansion duplex, low pressure Worthington pump of large capacity and low head, separately steam driven centrifugal Lawrence pump, belt driven centrifugal pump, a high pressure pump and accumulator of the Worthington type for 1500 lbs., and a second for 5000 lbs. pressure. Two hot air engines, and several internal combustion engines, including the Nash, fitted to operate on various fuels, a Hornsby-Akroyd and a Mietz and Weiss oil engine, an old and a new style Otto, an International Harvester, a Daimler boat engine are equipped for gas engine test and investigation work of great variety. From time to time other machines are secured for short periods of time for testing purposes. For the study of refrigeration there is installed a small Brunswick ammonia compression ice-making and refrigerating unit, motor driven, and a larger De La Vergne steam-driven, ice-making plant.

COURSE LEADING TO THE DEGREE OF MECHANICAL ENGINEER

All the subjects leading to the degree of Mechanical Engineer are listed in the following table, together with the year and term in which they are given. The first two years are devoted to essential preparatory and fundamental subjects, mathematics, chemistry, physics, analytical mechanics and drawing which are co-ordinated with kinematics, elementary design, shop work and the elements of electrical and steam engineering. In the third year there are developed the basic principles of thermodynamics, resistance of materials and hydraulics, which are fixed in the mind of the student by drill in the drafting room by design courses, in the laboratory by experiments and tests and in class by analysis of standard mechanical and electrical machinery. The fourth year is devoted to a detailed treatment of gas and steam engine design, standard water turbine characteristics and the essential relations between units constituting power plants and factories. Special attention is here paid to the economics of mechanical engineering by courses in industrial law, economics and works management. Throughout the course the aim is to develop clear conceptions of underlying principles, habits of independent thought and orderly mental procedure applicable to any sort of Mechanical Engineering problems rather than to the memorization of isolated facts. The training given not only fits the student to take up the design of machinery and the perfection of processes of doing things by mechanical means, but also to take ultimately a leading place in the management of the manufacturing and transportation industries.

FIRST YEAR

See page 27

SECOND YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
82	Drafting 7	Structural Drafting		
89	Mathematics 65	Calculus		3
90	Mech. Eng. 11	Steam Power Machinery	5	
92	Mech. Eng. 35	Kinematics	3	
95	Mech. Eng. 59	Empiric Design		3
108	Phys. Educ. B	Gymnasium	2	3
109	Physics 5	Electricity		2
109	Physics 43	Physical Laboratory	5	
111	Shopwork 1	Pattern Making		3
				6
		Total..	15	20
		Second Half Year		
72	Chemistry 82	Industrial Chemistry		
83	Elect. Eng. 2	Elements of Electrical Engineering	3	
90	Mech. Eng. 12	Steam Power Machinery	2	
92	Mech. Eng. 36	Kinematics	3	3
109	Mechanics 102	Analytical Mechanics		3
100	Metallurgy 134	Iron and Steel	5	
108	Phys. Educ. B	Gymnasium	2	
109	Physics 44	Physical Laboratory		2
111	Shopwork 2	Moulding and Foundry Practice		3
111	Shopwork 12	Forging		3
				6
		Total..	15	20

SUMMER WORK: Shop Work 108. 125 hours in College shops; Mech. Eng. 94s. 6 weeks practical work in shops and drafting rooms of manufacturing establishments, with report. A total of 9 weeks.

THIRD YEAR

See Page		*First Half Year*	Hours per week: Class	Lab'y & Draft'g.
77	Civil Eng. 53	Resistance of Materials	5	3
83	Elect. Eng. 73	Direct Current Laboratory		3
84	Elect. Eng. 101	Dynamo and Motor Practice	2	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
92	Mech. Eng. 31	Standard Tests	1	3
93	Mech. Eng. 39	Machine Design	3	3
109	Mechanics 105	Thermodynamics	2	
111	Shopwork 11	Machine Shop		6
		Total..	15	18
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 78	Hydraulics	2	
85	Elect. Eng. 104	Electric Distribution	3	
90	Mech. Eng. 18	Engineering Thermodynamics	2	
92	Mech. Eng. 32	Standard Tests	1	3
93	Mech. Eng. 40	Machine Design		9
94	Mech. Eng. 54	Shop Processes	2	
95	Mech. Eng. 64,	Air Machinery	2	
96	Mech. Eng. 66,	Elevators and Conveyors	1	
96	Mech. Eng. 70,	Pumping Machinery	2	
95	Mech. Eng. 60	Hydraulic Laboratory	1	3
101	Metallurgy 156	Metallographic Laboratory		
		Total..	16	18

SUMMER WORK: Mech. Eng. 96s. 6 weeks practical work in power plant, with report

FOURTH YEAR

		First Half Year		
84	Elect. Eng. 103	Electric Power	2	
85	Elect. Eng. 105	Electrical Distribution	2	
90	Mech. Eng. 19	Engine Design	3	6
91	Mech. Eng. 21	Gas Power	4	3
91	Mech. Eng. 25	Steam Power	2	3
92	Mech. Eng. 33	Standard Tests	2	3
93	Mech. Eng. 45	Water Power	3	0
		Total..	18	15
		Second Half Year		
84	Elect. Eng. 76	Alternating Current Laboratory	1	3
82	Economics 2	Economics	3	
89	Law 2	Business Law	3	
90	Mech. Eng. 20	Engine Design	3	6
91	Mech. Eng. 26	Steam Power	2	6
93	Mech. Eng. 50	Steam Turbines	3	
94	Mech. Eng. 52	Organization and Management	3	
		Total..	18	15

CHEMISTRY

General Statement

The regular four-year courses of instruction herein shown are designed for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges and scientific schools, or as chemists or managers in manufacturing and other industrial enterprises.

There are two courses offered, leading to the degrees of Chemist and Chemical Engineer respectively.

Equipment

In Havemeyer Hall the Chemical Department is provided with space for its museum, lecture-rooms, and laboratories, and every convenience has been furnished for both the instructors and students working in the general or special courses.

There are five chemical lecture-rooms, all fully supplied with apparatus and instruments, the desks being equipped with pneumatic troughs, gas, pressure, exhaust, and electricity. The large chemical lecture-room on the ground floor contains 315 seats.

The Chandler Museum of General Inorganic and Organic Chemistry and of the Chemical Arts, a large room occupying the whole left wing of the ground floor, contains the elements and all their more important compounds, inorganic and organic; materials and products illustrating the chemical arts, and numerous models, pictures, and diagrams.

The new William H. Nichols Laboratories for General Inorganic Chemistry and Qualitative Analysis, together with the rooms for instructors and for research, occupy the whole of one floor of Havemeyer Hall. They are fitted up in the most modern and complete way, with all the conveniences required for instruction and investigation.

The Quantitative Laboratory has eighty-eight desks. Attached to the main laboratory is a large, well-equipped balance-room, containing accurate balances, and special rooms, provided with apparatus for gas, water, food, and electrolytic analysis.

The Organic Laboratory has forty large desks, provided with gas, water, exhaust, and electricity, and has special rooms for balances, pressure ovens, and glass-blowing.

The Laboratory of Industrial and Engineering Chemistry, for the instruction of students in practical application and the solution of problems in connection with the chemical industries, is equipped for the manufacture of pure chemicals from their raw materials on a large scale, with batteries of steam evaporators, and with steam stills, centrifugals, filter presses, crushers, vacuum dryers, multiple effect evaporators, stills and general apparatus for industrial research. It includes

a textile and paper laboratory containing a calico printing machine, paper making machinery, etc., and the regular equipment for practical research. Connected with it is a photometer-room containing a new and complete outfit for the practical testing of illuminants.

A new Laboratory for Applied Electrochemistry has been provided. The equipment consists of special motor-dynamos, one of which furnishes direct current at low voltages to the students' desks for general electrolytic work; the other provides heavy alternating current to the electric furnace room; this room is furnished with all appliances for electric furnace work. The students' desks are fitted with special switchboards and measuring instruments, and the laboratory has been arranged for carrying on research work in all branches of electrochemistry.

The Laboratory of Physical Chemistry is well equipped with the most recent apparatus adapted to a wide range of experimental work in the branches of heat, light, and electricity as applied to chemical problems.

The Chemical Library in Havemeyer Hall is supplied with an extensive collection of chemical books and journals, and is open from 9.00 A.M. to 5.00 P.M., and during the session of the University from 8.00 to 11.00 P.M.

COURSE LEADING TO THE DEGREE OF CHEMICAL ENGINEER

The course in chemical engineering, as will be seen, is designed to educate chemists with a sufficient amount of engineering to fit them to take charge of chemical industries which depend upon the application of engineering methods and appliances to the manufacture of chemical products. This requires a knowledge of mechanical engineering, electrical engineering, hydraulics, mechanical drawing, shopwork, etc., as well as a thorough knowledge of chemistry in all its branches.

FIRST YEAR

See page 27

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Organic Chemistry	2	
74	Chemistry 81	Industrial Chemistry	3	
73	Chemistry 163	Quantitative Analysis	3	12
89	Mathematics 65	Differential Integral Calculus	5	
104	Mineralogy 15	Determinative Mineralogy		3
109	Physics 5	Electricity	5	
109	Physics 43	Physical Laboratory		3
108	Phys. Educ. B	Gymnasium		2
		Total..	18	20
Second Half Year				
72	Chemistry 42	Organic Chemistry	2	
74	Chemistry 82	Industrial Chemistry	3	
73	Chemistry 164	Quantitative Analysis	3	12
83	Elect. Eng. 2	Elements of the Dynamo	2	
109	Mechanics 102	Analytical Mechanics	5	
104	Mineralogy 16	Determinative Mineralogy		3
109	Physics 44	Physical Laboratory		3
108	Phys. Educ. B	Gymnasium		2
		Total..	15	20

SUMMER WORK: Chemistry 80a, 1 week. Shopwork 18s (8), 3 weeks in June or July.

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	3
72	Chemistry 149	Organic Chemistry	2	9
74	Chemistry 83	Industrial Chemistry	3	
71	Chemistry 101	Advanced Inorganic	2	
90	Mech. Eng. 11	Steam Power Machinery	3	
95	Mech. Eng. 59	Empiric Design	2	3
		Total..	17	15
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 78	Hydraulics	2	
74	Chemistry 84	Food Chemistry	3	
71	Chemistry 102	Advanced Inorganic	2	
83	Elect. Eng. 4	Direct Current Laboratory		3
83	Elect. Eng. 72	Electric Distribution	2	
89	Law 2	Business Law	2	
90	Mech. Eng. 12	Steam Power Machinery	3	3
102	Metallurgy 182	Assaying	2	6
		Total..	16	15

SUMMER WORK: Chemistry 80b. Visits to Industrial Plants—2 weeks. Chemical Factory work with Report—6 weeks.

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	
73	Chemistry 171	Organic Analysis	2	6
75	Chemistry 197	Chemical Factory Machinery }		
98	Mech. Eng. 97	Mechanical Equipment of Chemical Factories }	5	
90	Mech. Eng. 17	Technical Thermodynamics	2	
93	Mech. Eng. 37	Machine Design	1	6
97	Mech. Eng. 77	Experimental Engineering Laboratory	1	3
98	Metallurgy 101, 111	Introduction and Metallurgy of Copper	3	
100	Metallurgy 131	Iron and Steel	1	
		Total..	18	15
		Second Half Year		
75	Chemistry 88	Industrial Laboratory		9
71	Chemistry 122	Physical Chemistry	3	3
75	Chemistry 184	Practical Electro-Chemistry	2	3
75	Chemistry 198	Chemical Factory Organization	3	
90	Mech. Eng. 18	Technical Thermodynamics	2	
96	Mech. Eng. 76	Experimental Engineering Laboratory	1	3
99	Metallurgy 122	Metallurgy of Gold, Silver, Lead, Zinc	3	
		Total..	14	18

COURSE LEADING TO THE DEGREE OF CHEMIST

The course in chemistry includes not only all branches of theoretical, analytical, and industrial chemistry, but also collateral sciences, such as mathematics, mechanics, physics, mineralogy, metallurgy, mechanical and electrical engineering, and drawing, which have been found by experience to be required by the professional chemist. It is the intention to provide the graduate not only with a thorough knowledge of the principles and practice of chemistry in all its branches, but with such a broad and liberal education in the collateral sciences as will prepare him for every demand that will be likely to be made upon him in connection with his profession or in the pursuit of investigation.

FIRST YEAR

See page 27

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Elementary Organic—Lecture Course	2	
74	Chemistry 81	Industrial Chemistry	3	
73	Chemistry 163	Quantitative Analysis	3	12
108	Mathematics 65	Differential and Integral Calculus	5	
104	Mineralogy 15	Determinative Mineralogy		3
109	Physics 5	Electricity	5	
108	Phys. Educ. B	Gymnasium		2
		Total..	18	17
Second Half Year				
72	Chemistry 42	Elementary Organic—Lecture Course	2	
74	Chemistry 82	Industrial Chemistry	3	
73	Chemistry 164	Quantitative Analysis	3	12
83	Elect. Eng. 2	Elements of Dynamo	2	
109	Mechanics 102	Analytical Mechanics	5	
104	Mineralogy 16	Determinative Mineralogy		3
108	Phys. Educ. B	Gymnasium		2
			15	17

SUMMER WORK: Chemistry 80a—Memoir.

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
74	Chemistry 83	Industrial Chemistry	3	
71	Chemistry 101	Advanced Inorganic	2	
71	Chemistry 121	Physical Chemistry	3	3
73	Chemistry 171	Organic Analysis	2	6
74	Chemistry 175	Food Analysis	2	6
75	Chemistry 183	Industrial Electrochemstry	2	3
		Total..	14	18
		Second Half Year		
74	Chemistry 84	Food Chemistry	3	
75	Chemistry 88	Industrial—Laboratory Course		9
71	Chemistry 102	Advanced Inorganic Chemistry	2	
71	Chemistry 122	Physical Chemistry	3	
102	Metallurgy 182	Assaying	2	6
104	Mineralogy 10	Practical study of crystals.	2	3
		Total..	12	18

SUMMER WORK: Chemistry 80b—Memoir.

FOURTH YEAR

		First Half Year			
70	Chemistry 7	Inorganic Chemistry—or	Elective or taken from afternoons	(2)	
71	Chemistry 23	Physical Chemistry—or			
75	Chemistry 93	Electro Chemistry—or			
75	Chemistry 95	Industrial Chemistry—or			
72	Chemistry 143	Organic Chemistry—or			
73	Chemistry 167	Adv.Inorg.Anal.Chem.—or			
73	Chemistry 173	Adv. Org. Anal. Chemistry			
75	Chemistry 89	Industrial Chemistry—Lab. Practice			3
72	Chemistry 141	Organic Chemistry—General Course		5	12
98	Metallurgy 101, 111	Introduction and Metal'gy of Copper		3	
100	Metallurgy 131	Iron and Steel		1	
		Total..		11	15
		Second Half Year			
72	Chemistry 142	Organic Chemistry—General Course		5	
99	Metallurgy 122	Lead, Silver, Gold and Zinc		3	
	Thesis—			2	15
70	Chemistry 8	Inorg. Chemistry—or			
71	Chemistry 24	Physical Chemistry—or			
75	Chemistry 94	Electro-Chemistry—or			
75	Chemistry 96	Industrial Chemistry—or			
72	Chemistry 144	Organic Chemistry—or			
73	Chemistry 168	Adv. Inorg. Anal. Chemistry—or			
73	Chemistry 174	Adv. Org. Anal. Chemistry—or			
74	Chemistry 176	Food Chemistry			
		Total..		10	15

COURSES OF INSTRUCTION

Arranged Alphabetically by Departments

ASTRONOMY

105—**Geodesy.** 3 hours. Professor S. A. MITCHELL.

Brief history of geodetic operations and description of theodolites, base apparatus, and other instruments used in geodetic work, including their adjustment and use. Text-book: Wilson's *Topographic Surveying.*

106—**Geodesy.** 1 hour and 1 laboratory period. Professor S. A. MITCHELL.

The applications of practical astronomy to geodetic surveying, and training in methods of accurate computation. Text-book: Hosmer's *Practical Astronomy.*

107s—**Geodetic Surveying.** Professors JACOBY and S. A. MITCHELL, with Assistants.

Summer Course in Practical Geodesy: Given at Camp Columbia, Morris, Conn.
Pre-requisite for all courses: Mathematics of first two years.

BACTERIOLOGY

101—**Sanitary Bacteriology.** 2 hours and 2 afternoons a week for nine weeks. Professor HISS and Assistants.

Practical instruction in Bacteriology and Hygiene. A short course for Sanitary Engineering Students, adapted from and covering the more important topics treated in Courses 51 and 201. The course opens with the study of the relationship of bacteria to other micro-organisms. It embraces the methods of staining, examining, and cultivating. The student is taught by practical exercises the methods of separating one species of bacteria from another, and the series of biological characters used in identification of the various forms. The general and special relationship of micro-organisms to disease is considered. Finally some of the hygienic aspects of bacteriology are studied by experiments in the sterilization of infectious material, disinfection of the hands, and by practice in the biology of air, water, milk, and other foods, and soil analysis. For students in Sanitary Engineering.

Pre-requisite: Chemistry, 65.

BOTANY

7—**Growth and Character of Timber.** 1 hour and 1 afternoon. Professor CURTIS and Dr. DARLING.

Growth of the tree, character and arrangement of its tissues; relation of moisture to strength of timber; the deterioration, preservation, distribution and identification of lumber.

Second year for Civil Engineering students.

CHEMISTRY

The following courses in Chemistry are included in the programs of study of the Schools of Mines, Engineering and Chemistry. For other courses offered see the *Announcement of the Division of Chemistry.*

Inorganic Chemistry

3 or 4—**General Inorganic Chemistry.** 3 hours class-room. Professor SMITH.

Pre-requisite: Course Chem. A or Entrance Examination in Chemistry.

7-8—**Inorganic Chemistry.** 2 hours lectures or conferences throughout the year and 5 afternoons laboratory the second half-year. Professor SMITH.

Designed for fourth-year students in the course of chemistry selecting a thesis in inorganic chemistry.

61 or 62—Qualitative Analysis. 4 hours and 5 afternoons. Professor BEANS, Dr. MOORE.

Theory and practice of qualitative inorganic analysis based upon the principles of physical chemistry.
Pre-requisite: Chemistry A or Entrance. Parallel, Chem. 3-4.

101-102—Advanced Inorganic Chemistry. 2 lectures. Professor SMITH.

Descriptive inorganic chemistry and the application of the laws and theories of chemistry and of modern views to chemical problems.
Pre-requisite: Courses 3-4 and 61-62.

Summer Courses

For details, see the *Announcement of the Summer Session.*

sA (s6)—General Chemistry. 5 hours lectures, 12 hours laboratory work, and 2 hours recitations.

s61-62—Qualitative Analysis. 10 hours lectures and conferences, and 30 hours laboratory work a week. Professor BEANS and Assistant.

Extension Teaching, Evening Courses

For details see the *Announcement of Extension Teaching.*

eA1-eA2—General Chemistry, College Course. Elementary course for students beginning the study of chemistry. 2 lectures, 1 recitation and 2 hours laboratory practice, counting as 4 points each half year. This course is a duplication of the day course A1-A2. Dr. NEISH.

Physical Chemistry

21-22—Elementary Physical Chemistry. 2 hours lectures and recitations first half-year and 3 hours second half-year, with laboratory work 15 afternoons second half-year (equivalent to 1 afternoon throughout the half-year). Professor MORGAN and Assistant.

Text-books: Portions of Morgan's *Physical Chemistry for Electrical Engineers* and Ostwald's *Physico-Chemical Measurements.*
Pre-requisite: Course 3-4 and Physics 3-4.

121-122—Physical Chemistry. 3 hours lectures and recitations during the entire year, and 15 afternoons, equivalent to 1 afternoon a week, laboratory during the first or second half-year. Professor MORGAN and Assistant.

A course treating of the states of aggregation, solution, and ions in analytical chemistry, thermo-chemistry, chemical mechanics, and electro-chemistry. Text-books: Morgan's *Elements of Physical Chemistry,* and Ostwald's *Physico-chemical Measurements.*
Pre-requisite: Course 3-4 and 61-62, Physics 3-4 and Mathematics 64-65.

38—Theoretical Electro-chemistry. 2 hours lectures and recitations. Professor MORGAN.

Text-book: Portions of *Morgan's Physical Chemistry for Electrical Engineers.*
Pre-requisite: Course: 3-4 and 65, Physics 3-4, and Mathematics 64-65.

23-24—Physical Chemistry. 2 hours in lectures or conferences throughout the year, and 5 afternoons laboratory during the second half-year. Professor MORGAN.

Designed for four-year students in the course of chemistry, selecting a thesis in physical chemistry.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s138—Elementary Physical Chemistry. 5 hours. Professor MORGAN.

Research. The laboratory is open to properly qualified students for research under the direction of Professor MORGAN.

Organic Chemistry

41-42—Organic Chemistry, Introductory Lecture Course. 2 hours. Dr. NELSON.

An introductory course, which can be taken with advantage by college students and by those expecting to enter the medical course. Instruction given on such important classes of compounds as the hydrocarbons, alcohols, ethers, organic acids, fats, waxes, soaps, cyanides, sugars, carbohydrates, alkaloids, coloring matters, drugs, perfumes, and the like. The lectures will be liberally illustrated by material from the Chemical Museum. Text-book: Perkin & Kipping's *Organic Chemistry.*

Pre-requisite: Course **3-4** and **61** or **62.** It is urged that, if possible laboratory work, Course **43-44**, be taken with this elementary lecture course.

43-44—Organic Chemistry, Introductory Laboratory Course. 8 hours. Dr. NELSON and Instructor.

A study of the typical methods for preparation and the typical reactions of the important classes of organic compounds. Text-book: Gattermann's *Practical Methods of Organic Chemistry.*

Pre-requisite: Courses **3-4** and **61** or **62.** Pre-requisite or parallel: Course **41-42.**

141-142—Organic Chemistry, General Course. 3 lectures and 2 recitations a week for one year, and 4 afternoons laboratory the first half-year. Professor BOGERT, Dr. NELSON and Instructor.

A more comprehensive treatment of the subject, including a discussion of all the important classes of organic compounds. In the laboratory a large number of typical organic substances are prepared synthetically, and instruction given in the methods of qualitative and ultimate organic analysis. Text-books: Holleman's *Organic Chemistry,* Gattermann's *Practical Methods of Organic Chemistry.*

Pre-requisite: Courses **3-4, 21-22,** and **161-162.**

143-144—Organic Chemistry, Conferences. 2 hours. Professor BOGERT.

Presentation and discussion of recent important investigations in the field of organic chemistry.

Required, together with 5 afternoons laboratory practice the second half-year, of all fourth-year students in the School of Chemistry selecting a thesis in organic chemistry. Pre-requisite or parallel: Course **141-142.**

149—Advanced Organic Chemistry for Chemical Engineering Students. 2 lectures and 3 afternoons. Dr. NELSON and Instructor.

The study of organic compounds and reactions with particular reference to their relation to commercial products and manufacturing processes.

Pre-requisite: Course **41-42** or its equivalent. Required of all third-year chemical engineering students.

151-152—Advanced Organic Chemistry, Laboratory Course. 2 afternoons. Professor BOGERT, Dr. NELSON and Instructor.

The synthesis and study of any one of such important groups of organic compounds as (*a*) dyestuffs, (*b*) essential oils, (*c*) alkaloids, (*d*) synthetic drugs and organic substances of special interest to the medical profession, or similar groups to be selected by conference with the instructor.

For chemical engineers electing a thesis in organic chemistry, 3 afternoons, second half-year.

Pre-requisite: Courses 3-4, 41-42, and 43-44.

Summer Courses

S41-42—Organic Chemistry, Elementary Lecture Course. 10 hours. Dr. NELSON and Assistant.

S43-44—Organic Chemistry, Laboratory Course. Dr. NELSON and Assistant.

Research. The laboratory is open to properly qualified students for research under the direction of Dr. NELSON.

Analytical Chemistry

65—Quantitative Analysis, Inorganic, Short Course. 2 hours and 2 afternoons. Professor METZGER and Instructors.

The analyses included in this course are: Magnesium sulphate, potassium alum, coal, iron ore, copper, zinc, alkalimetry, acidimetry, and flue gas. Text-books: Miller's *Notes on Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

Pre-requisite: **Courses 3-4 and 61 or 62.**

66—Quantitative Analysis, Inorganic. 3 hours and 4 afternoons. Professor METZGER and Instructors.

The analyses included in this course are: Magnesium sulphate, potassium alum, iron-ammonium alum, coal, iron ore, pig iron, spiegel, zinc ore, limestone, slag, copper, lead, arsenic, antimony, ores, and flue gas. Text-books: Miller's *Notes on Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

Pre-requisite: **Courses 3-4 and 61 or 62.**

161-162—Quantitative Analysis, Inorganic. 1 hour and 8 hours laboratory. Professor METZGER.

Text-book: Talbot's *Quantitative Analysis.*

Pre-requisite: **Courses 3-4 and 61 or 62.**

163-164—Quantitative Analysis. 163—3 hours, 164—4 hours and 4 afternoons. Professor METZGER and Instructors.

The classroom work includes not only the methods applied in the laboratory, but discussions of quantitative separations from a theoretical standpoint, and chemical calculations. Text-books: Treadwell's *Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

The analyses included in this course are: Magnesium sulphate, sodium or other chloride, potassium alum, iron ammonium alum, coal, iron ore, pig iron, spiegel, limestone, slag, feldspar, ores of zinc, copper, nickel, lead, chromium, arsenic, antimony, alloys, rocks, gas analysis, etc.

Pre-requisite: **Courses 3-4 and 61 or 62.**

167-168—Advanced Inorganic Analysis. 2 hours. Professor METZGER.

Laboratory practice 5 afternoons during the second half-year for students in the course of Chemistry, who elect thesis work in inorganic analytical chemistry.

A systematic study of the separation and determination of the elements, including the rare elements.

Pre-requisite or parallel: **Chemistry 101-102, 121-122, 163-164.**

171—Organic Analysis. 2 hours and 2 afternoons. Professor SHERMAN and Instructor.

The lectures include general and industrial organic analysis, fertilizer analysis and inspection, examination of drinking water. Special attention is given to the interpretation of the analytical results. Text-books: Sherman's *Methods of Organic Analysis* and Mason's *Examination of Water.*

The analyses included in this course are: Acidimetry and alkalimetry, alcohol, sugars, lubricating and other industrial oils, soap, fertilizers, and the sanitary analysis of water.

Pre-requisite: Chemistry **41-42** and **161-162.**

173-174—Advanced Organic Analysis. 2 hours. Professor SHERMAN.

Laboratory work during the second half-year 5 afternoons for fourth-year stu-

dents in the Chemistry course who elect thesis work in organic analytical chemistry or food chemistry.

The analytical chemistry of proteins and their derivatives, alkaloids, tannins and fibres; plant analysis; advanced methods in food analysis; measurement of the activity of enzymes and the digestibility and nutritive value of food; systematic review of organic analysis.

Pre-requisite or parallel: Chemistry **171** or **175**.

175—Food Analysis. 2 hours and 2 afternoons. Professor SHERMAN and Instructor.

The class-room work of this course includes a discussion of the descriptive and analytical chemistry of the principal constituents of foods, and some of the more important enzymes connected with the utilization of foods, as well as the analysis of commercial food products. Special attention is given to the interpretation of the results of food analysis in relation to official standards of composition and purity. Text-book: Sherman's *Methods of Organic Analysis.*

The analyses included in this course are: Sugars, starches, cereals and breadstuffs, edible oils, butter, milk, and food preservatives.

Pre-requisite: Chemistry **41-42** and **161-162**.

176—Chemistry of Food and Nutrition. 3 hours. Professor SHERMAN.

The chemistry and functions of the foodstuffs; the composition and nutritive values of food materials; the amounts of food required in nutrition; methods of determining the nutritive values of special foods and the effects of adulteration; food legislation and inspection; standards of purity for food products; normal and abnormal variations in compositions. Text-book: Sherman's *Chemistry of Food and Nutrition.*

Pre-requisite: Chemistry **41**.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s161-162—Quantitative Analysis. 5 hours lectures and 30 hours laboratory work a week (accepted for Course 65). Professor METZGER.

sF—Chemistry of Nutrition. 5 hours lectures. Professor SHERMAN.

s171a—Organic and Sanitary Analysis. Conferences and laboratory. Professor SHERMAN and Assistant.

s171b—Food Analysis and Inspection. Professor SHERMAN.

Research. The laboratory is open to properly qualified students for research, in organic analytical chemistry or the chemistry of foods, under the direction of Professor SHERMAN.

Industrial Chemistry

81-82—Industrial Chemistry, General. 3 hours lectures. Professor WHITAKER and Dr. KRESS.

Air; water; sulphur; sulphuric acid; nitric acid; hydrochloric acid; alkali industries; potash; artificial gases and natural gas; petroleum and its products; cement; paints and varnishes; soaps; ceramics; glass; explosives; fuels; structural materials.

Pre-requisite: Courses Chemistry **3** or **4** and **61** or **62**.

83—Industrial Chemistry, Advanced Course. 3 hours. Dr. KRESS.

Textile; tanning; glue and gums; India rubber and plastics; celluloid; artificial fibers; paints, oils, varnishes; paper; photography, etc.

Pre-requisite: Courses Chemistry **3-4** and **81-82** or **41-42**.

84—Food Chemistry. 3 hours. Professor SHERMAN.

The general principles of food chemistry and food legislation and the chemical technology and control of the more important food industries; milk and its products; meat products; edible fats and oils; grain products; starch, glucose, sugar; fruit products; fermentation; etc.

Pre-requisite: Chemistry **3** or **4** and **81-82** or **41-42**.

88—Industrial Chemistry, Laboratory Practice. 3 afternoons. Professor WHITAKER and Dr. KRESS.

Fourth-year students in Chemical Engineering.

89—Industrial Chemistry, Laboratory Practice. 1 afternoon. Dr. KRESS.

Special applications: Textile industry, vegetable and animal fibres, bleaching, dyeing, and calico printing. Including instruction in the use of the microscope.
Pre-requisite: Course 3 or 4, 41 or 42.

95-96—Industrial Chemistry. 2 hours throughout the year, and 5 afternoons in the laboratory during the second half-year. Professor WHITAKER and Dr. KRESS.

Designed for fourth-year students in the course of chemistry selecting a thesis in industrial chemistry.

197—Chemical Factory Apparatus and Machines. 5 hours. Professors WHITAKER and THOMAS.

To cover the construction and use of the apparatus and machinery of chemical factories.

198—Chemical Factory Management. 3 hours. Professor WHITAKER.

Relations of the chemist to the various phases of making and marketing chemical products. Sales organization and methods; transportation of products and materials; purchase of supplies; warehousing and stocks; manufacturing organization; equipment; process; operation; cost keeping and accounting; process improvements; product improvements; factory economics; labor; insurance; fire and accident protection; finance; administration.

80a—Factory Inspection and Summer Memoir. Professor WHITAKER and Dr. KRESS.

Visiting and inspection of chemical works of special interest in and near New York City, such as gas works, petroleum refineries, paint and varnish factories, soap and candle works, and plants for the purification of water and sewage.
Required of all second-year students in the courses of chemistry and chemical engineering. The visits to factories are made during the weeks following the final examinations.

80b—Summer Factory Excursion Work and Report. Professor WHITAKER and Dr. KRESS.

Two weeks is devoted to a study of industrial plants in New York and neighboring cities. Students will also be required to work at least six weeks in a chemical factory or laboratory or in some position approved by the instructor. Full report on this requirement will be made to the instructors at the conclusion of the work.

Electro-Chemistry

93-94—Electro-Chemistry. 2 hours throughout the year, and 5 afternoons during the second half-year. Professor TUCKER.

Designed for fourth-year students in the course of chemistry or chemical engineering selecting a thesis in electro-chemistry.

181-182—Practical Electro-Chemistry. 10 hours. Professor TUCKER.

Electroplating, influential factors in electrolysis, the use of diaphragms, electrolysis of fused salts, electrolytic preparations, metal refining, electric furnace practice, and preparation of carbides, silicides, etc., measurement of high temperatures.
Pre-requisite: Courses 3 or 4, 61 or 62, 65.

183-184—Industrial Electro-Chemistry. 1 hour and 14 afternoons. Professor Tucker.

The applications of electrolysis and the electric furnace to the production and purification of chemicals and metals. Illustrated by short laboratory course.
Pre-requisite: 3 or 4, 65.

CIVIL ENGINEERING

2—Theory of Surveying. Lectures and recitations, 2 hours. Professor LOVELL, Mr. FINCH and Assistants.

Methods of measuring angles and distances. Cumulative and compensating errors, and corrections to be applied. Limits of precision. Use, care, and adjustment of the engineer's transit, level, and compass. Magnetic declination and variation. Local attraction. Relocation of old lines by compass bearings. Erroneous standards. Surplus and deficiency. Significance of monuments. Traverses; computations of area and error of closure. Laying out and dividing up land. System of public land surveys. Topographic surveys; transit stadia and plane table methods. Triangulation. City surveying, subdivision and resurveys. Interpretation of deed descriptions. Text-book: Tracy's *Plane Surveying*.
For all first-year students in Chemistry.

15—Surveying between the First and Second Years. Field work and office work. 5 weeks. 4 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Survey 1 includes pacing and chaining, ranging out lines, contouring with hand level, mapping. *Survey 2* consists of the adjustment of the level and in running a line of differential levels. Note book and report. *Survey 3* consists of the adjustment of the transit, angle reading by repetition, determination of stadia constant, observations to determine reliability of the compass, the survey of a closed field or farm, measuring the boundary lines by steel tape and the angles or directions by transit and locating the principal topographic details by stadia. Notebook, computation of area and map. *Survey 4* consists of repetition traverse of a closed field, distances being measured by steel tape corrected for catenary, pull, and temperature. Determination of magnetic declination by observation on Polaris.
Pre-requisite: 2.

21—Highway Engineering. 2 hours. Professor LOVELL.

Road resistances—Design, construction, maintenance and repair, of Dirt, Gravel, Broken Stone and Miscellaneous Roads—Street Location—City pavements—Belgian and Granite Block, Brick, Asphalt and Wooden Block—Foundations—Grades—Drainage, Specifications. Reference and text-books: *Roads and Pavements*, Baker.

23—Theory of Railroad Surveying. 2 hours and 1 afternoon. Professor LOVELL and Mr. FINCH.

An abridged course, for students in Mining Engineering, covering the same subjects as are taken in Course 51-52.
Pre-requisite: 15.

25—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Survey 1 consists of running a line of levels for a water main or sewer, plotting profile, and computation of excavation. *Survey 2* consists of a topographic survey with plane table. Intersection, re-section, and traverse methods to be used, and map made. *Survey 3* consists of a topographic survey with transit and stadia; note-book and map. An optional course in photographic surveying may be offered in 1912. *Survey 4* consists of solar observations with transit and solar compass for the determination of the true meridian and magnetic declination. *Survey 5a*, City surveying, consists of the division of land into city blocks and subdivision into lots and the location of the street and lot lines; grade lines for streets and grades at street intersections; location and grade of sewers; including map, profile, and computation of excavation for street opening and sewer line. Relocation of lot lines and problems in surplus and deficiency, map showing property with record line and encroachments. Location of lines for buildings, bridge abutments, etc.
Pre-requisite: 15.

26—Surveying between the Third and Fourth Years. Hydrographic Survey. Field and office work 2 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Survey made in conjunction with Geodetic Survey (total time 5 weeks, see page 70, Dept. of Astronomy), which furnishes main triangulation net for topo-

graphic and hydrographic control. Hydrographic survey consists of auxilliary triangulation, topography on shore by stadia, soundings, observations on outlet by current meter for river discharge, adjustment of angles, computation of triangulation system, also of river discharge, may and report.

Pre-requisite: 25.

27—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Same as C. E. 25 except *Survey 5a* is omitted and *Survey 5b* is added. *Survey 5b* consists of the location of a mining claim 1,500 feet long by 300 feet wide in conflict with existing claims, and the determination of the areas in conflict. The claim is located upon an outcrop of assumed dip and strike, in such a manner as to keep the center line close to the outcrop. Reports and maps.

Pre-requisite: 15.

28—Surveying between the Second and Third Years. Field work and office work. 3 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Railroad surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computation—Economic comparisons from construction and operating standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, calculations of earthworks, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 23, 27.

51-52—Theory of Railroad Surveying. 2 hours and 1 afternoon, first half-year, and 3 hours and 1 afternoon second half-year. Professor LOVELL and Mr. FINCH.

Simple, compound, and reversed curves—Transition curves—Switch work—Cross-section work—Earthwork computations—Cost of earthwork; cut and fill—Borrow—Waste and overhaul—Office work; Profile with mass curve showing proper distribution of excavation. Lectures and practical problems. Reference books: Searle's *Field Engineering* and Crandall's *Transition Curve and Earthwork.*

Pre-requisite: 15.

53-54—Elasticity and Resistance of the Materials of Engineering. 5 hours lectures and recitations first half. 6 hours first half-year of problem, design and laboratory work; 3 hours second half. Professors BURR and WILLIAMS, Mr. MACGREGOR and Mr. BRIGGS.

Laws of elasticity in homogeneous materials—Coefficients of elasticity—Relations between stresses and strains—Common and exact theories of torsion and flexure—Elastic limits, working stresses, and ultimate resistances of wrought iron, cast iron, steel, alloys, timbers, building-stones, cement, concrete, and masonry—Reinforced concrete construction—Complete treatment of simple and continuous beams—The design and construction of iron, steel, and timber columns and beams, including the design and construction of plate girders—Shafts—Cables—Fatigue of materials—Specifications—Testing Laboratory—Discussion of properties of structural materials as shown by results of testing, by tension, compression, bending, and torsion—Report of tests. Reference and text-book: Burr's *Elasticity and Resistance of Materials.*

Pre-requisite: Mechanics 102.

55—Standard Methods of Water Analysis. 2 afternoons.

Physical and biological.

Pre-requisite: Zoology 7, Bacteriology 101, Civil Engineering 59.

57a—Statistics and Interpretation of Water Analyses. 20 lectures.

Collection, preparation and interpretation of vital statistics, for the identification of the sanitary condition of particular States, cities, or communities as affected by water and milk supplies, sewerage systems, industrial and economic conditions. Interpretation of complete water analyses.

57b—Drainage of Marshes and Lowlands. A course of 10 lectures.

Mosquitos, habits, breeding, methods of extermination. Malaria, yellow fever.

Pre-requisites for courses **57a** and **57b** are Zoology **7**, Bacteriology **101**, and Civil Engineering **59**.

58—Masonry Structures. 3 hours and 1 afternoon with frequent conferences and continuous work in design. Cement and mortar testing in the cement-testing laboratory are required of all students. Professor WILLIAMS.

Pressure and abutting power of earth—Design and construction of retaining walls—Stability of masonry structures in general—Stability of towers and chimneys under wind pressure—Theory and design of arches with vertical and inclined loads—Theory and design of reservoir walls, earth and high masonry dams—Theory and Design of masonry domes—Cement, concrete, and masonry. Reference books: Ketchum's *Walls, Bins and Grain Elevators;* Morrison and Brodie's *High Masonry Dams,* and Baker's *Masonry and Foundations.*

Pre-requisite: Mechanics **102**, Mineralogy **5**.

59—Sanitary Engineering. 2 hours and 2 afternoons in January in Bacteriological Laboratory. Professor BLACK.*

Treatment and disposal of sewage and refuse of manufacturing—Sedimentation by gravity and by chemical precipitation—Treatment of effluent by continuous and intermittent sand filtration—Septic tanks—Contact beds—Percolating or trickling filters—Continuous flow tanks—Fertilization—Intermittent application to soil with under-drainage—Disposal of sludge—Plants for sewage treatment—Theory and construction of sand filters—Pollution of potable water and its purification by continuous and intermittent sand filtration—Mechanical filtration—Copper sulphate, ozone and other treatment for special waters—Design of sand filter for water purification—Examinations of and reports on typical purification works. Biology and Bacteriology of drinking water. Text-books: *Filtration of Public Water Supplies,* Hazen; *Purification of Sewage,* Kinnicut, Winslow and Pratt.

Pre-requisite: Chemistry **82**.

61—Analytical Theory of Trusses. 2 hours and 1 afternoon, with frequent conferences and problems in computations of stresses and preparation of stress sheets. Professor WILLIAMS.

The truss element—Simple cantilever and non-continuous trusses with parallel chords—Fixed and moving loads—Through and deck spans—Positions of any system of concentrated moving loads for greatest chord and web stresses when chords are both parallel and non-parallel—Combination of moments and graphic methods—Skew and irregular trusses—Applications to bridge and roof trusses—Braced arches and arched ribs. Reference and text-book: Burr and Falk's *Metallic Bridges.*

Pre-requisite: Mechanics **102**.

62—Graphic Statics. 2 hours and 1 afternoon. Professor WILLIAMS.

For students in Civil Engineering—Equilibrium polygon, and polygonal frames for all systems of loads—Graphical representations of shears and moments for both non-continuous and continuous beams—Fixed and moving loads—Lines of influence—Applications to bridge and roof trusses. Reference and text-book: Burr and Falk's *Influence Lines.*

Pre-requisite: Mechanics **102**.

64—Graphic Statics. 1 hour and 1 afternoon for mining engineers and metallurgist. Professor WILLIAMS.

An abridged course, covering the subjects taken in Course **62**.

Pre-requisite: Mechanics **102**.

*Absent on leave.

71—Surveying between the Third and Fourth Years. Field work and office work. 4 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Railroad Surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computations—Economic comparisons from construction and operation standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, earthwork quantities, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 51-52 and 25.

75—Hydraulics. 4 hours, with conferences and problems. Mr. FINCH.

Flow of water through orifices—Time required for discharge of canal locks and similar volumes—Weir discharge and gauging by weirs—Gauging of water for systems of irrigation—Flow through and discharge of pipes—Design of pipe systems for city waterworks—The Venturi meter—Flow in and discharge of open canals and rivers—Gauging of streams by current meters, floats and other means—Backwater—Flow of compressible fluids. Text-book: Merriman's *Hydraulics.*

Pre-requisite: Mechanics 102, Math. 64-65.

76—Hydraulics. 2 hours. Mr. FINCH.

For students in Mining Engineering—Course 75 abridged.

Pre-requisite: Mechanics 102, Math. 64-65.

77—Hydraulics. 2 hours. Mr. FINCH.

For students in Electrical Engineering—Similar to Course 75, but shorter. In addition it deals with the general considerations of rainfall, evaporation, percolation, run-off, net yield and storage; conduction of water from source to power-house, hydraulic losses and effective head on wheel; estimation of power. Text-book: Merriman's *Hydraulics.* Reference book: Turneaure and Russell's *Public Water Supplies.*

78—Hydraulics. 2 hours. Mr. FINCH.

For students in Chemical and Mechanical Engineering—Same as 76.

85—Foundations. 2 hours and 1 afternoon, with frequent conferences and continuous work in design. Professor BURR.

Earth foundations—Foundations for buildings—Safe loads on masonry and foundation beds—Pile driving and pile foundations—Safe loads for piles—Protection and preservation of piles and timber—Sheet piling and coffer-dam methods—Pneumatic foundations and caisson work—Open dredging—Bridge piers of masonry and cylinders—Piers for deep foundations—Methods of working in quicksands—Tunneling. Reference books: Patton's *Foundations* and Baker's *Masonry and Foundations.*

Pre-requisite: 58, Geology 18.

87-88—The Design and Construction of Bridges, Roofs, and Buildings. 2 hours and 1 afternoon, with frequent conferences and continuous work in design. Professors BURR and WILLIAMS.

Railway and highway bridges—Pin and riveted connections—Single and multiple system of bracing—The design of details for bridges, roofs, and buildings—Floors for railway and highway bridges—The design and operation of draw-bridges, including engines, locking, lifting, and turning machinery—Cantilever structures—Wind roads and stresses—Single and double-track viaducts or trestles in iron, steel, and timber—Lateral and transverse systems of bracing—The design and construction of elevated railroads—The complete designs of railway structures, with estimates of cost—The erection of iron, steel, and timber structures, including the cost of erection. First half-year only for sanitary engineers. Reference and text-books: Burr and Falk's *Influence Lines;* Burr and Falk's *Metallic Bridges.*

Pre-requisite: 53-54, 61-62.

89-90—Railroad Engineering. 3 hours and 2 afternoons for conferences and design work. Professor LOVELL and Mr. FINCH.

Location, construction and operation—Train resistance, sources and probable value—Curvature and grades, their relation to velocity and maximum train-load—Effect of momentum—Reduction of grades at starting points—Balance of grades for unequal traffic—Study of annual reports—Analysis of operating expenses—Cost of operating, including maintenance, per train mile—Itemized statements of costs and percentage to total cost—Cost of extra distance, curvature, rise and fall, or of additional trains—Effect of roadbed on cost of running trains—Justifiable expenditure in construction to save one mile of distance, one degree of curvature, one foot of rise and fall, or to reduce ruling grade .1% per daily train per year—Pusher grade for one or more assistant engines—Economical use of pusher grades—Cost of excessive or limiting curvature—Value of additional traffic—Principles to follow in locating new lines—General policy of improvements in old lines—Principles in design and construction of railroad yards and terminals—Computations and detail drawings of turnouts, slip switches and ladder tracks—Development and present practice in block signalling and interlocking, with problems in design and estimates of cost of installation—Classification and cost of earthwork—Graduation, cross section in excavation and embankment, and protection of slopes—Ordinary and extraordinary methods of drainage—Water supply, its quality, storage, and delivery—Design of standard maintenance of way plans, including ballast—Track and track accessories—Organization—Management. Reference books: Wellington's *Railway Location—Elements of Railroad Engineering*, Raymond—*American Railway Transportation*, Johnson—*The Block System*, Adams—Camp's *Notes on Track*—Dewsnap's *Railway Organization and Working*.

Pre-requisite: 71.

94—The Design and Construction of Sewers, and River and Harbor Improvements. 2 hours lectures, recitations, problem and design work. Professor BLACK.

Sewerage and surface drainage of cities and towns—Separate and combined systems of sewers—Capacities of mains and branches—Catch basins—Manholes—Chimneys or ventilators—Flush tanks—Outfalls—Grades—Flow or discharge of sewers—Construction. River and Harbor Improvements—Jetty system of river improvements—Scouring action of currents—Erosion of river banks—Dams for improvement of river navigation—Breakwaters—Dykes—Groins—Mattress work—Docks—Harbor works—Iron piers—Estimates of cost. Text and reference books: *Separate System of Sewerage*, Staley and Pierson—*Sewer Design*, Ogden—*Flow of Water in Open Channels, Pipes, etc.*, Flynn.

Pre-requisite: 26, 59, 75.

96—Principles of Hygiene, Sanitary Science and Public Health. 3 hours.

Health and disease; the germ theory of disease; dust and its dangers; infection and contagion; drinking water, ice, milk, vegetables, shell-fish, etc., as vehicles of disease; flies, fleas and other disease carriers; general problems of public health and sanitation. Personal hygiene.

Pre-requisite: Civil Engineering **57*a*** and **57*b***, Zoology **7**, Bateriology **101**, C. E. **59**.

97—Water-Supply and Irrigation Engineering. 2 hours lectures, recitations, problem and design work. Professor BLACK and Mr. FINCH.

Rainfall and storage—Flow of streams—influence of soils, elevation, geological character of water-shed—Methods of supply, gravitation, pumping from rivers or natural underground storage, flow from the latter, underground flow, wells—Reservoir construction—Distributing system. House supply and wastage. Irrigation of land—Amounts and periods of application—Construction of, and flow through, diversion and distributing canals. Text-book: *Public Water Supplies*, Turneaure & Russell.

Pre-requisite: 26, 59, 75.

99-100—Graduation Thesis. A project or thesis on some civil engineering subject, approved by the head of the department, is required of every candidate for the degree of Civil Engineer.

Advanced Courses

The minor subjects in the department of Civil Engineering for the University degrees of Master of Arts and Doctor of Philosophy (those courses which fulfill the residence requirements) are the following:

153-154—**Elasticity and Resistance of Materials.**

257-258—**Elastic and Masonry Arches.** Open to those who have taken 57-58. Conferences, reading and design work, as required.

275-276—Hydraulics (75 with additional reading).

285-286—**Foundations,** including theory of earth pressure (85 with additional reading).

287-288—**Long Span Bridges.** Open to those who have taken Civil Engineering 87-88. Conferences, with reading and design work as required.

291-292—**Railroad Location:** advanced work in the Economics of Railroad Location, including a study of railroad operation with special reference to the application of the economic principles in the re-location of some existing railway or the location of a proposed road. Plans, Profiles and Estimates. Pre-requisite: Courses 89-90.

The major subjects for the same University degrees are the following:

259-260—**Sanitary Engineering.** Pre-requisite: Courses 59, 94, 98.

277-278—**Hydraulic Engineering,** including the hydraulics of rivers and power plants and municipal water-works.

289-290—**The Engineering of Structures,** including long span sewage works, streets and other public works and their administration.

289-290—**The Engineering of Structures,** including long span bridges and deep foundations, with methods of building them, and advanced work in Elasticity and Resistance of materials.

293-294—**Railroad Engineering:** the design of the Permanent Way, including plans and specifications for roadbed, tunnels and culverts, track and track structures, yard and station layouts, block signals and interlocking. Pre-requisite: Courses 53-54, 58, 75, 85, 87-88, 89-90, and Mining Eng. 53.

DRAFTING

Equipment

The drafting rooms and offices, situated on the fourth floor of the Engineering building, are equipped with a standard form of drafting table, and have a seating capacity for 175 students.

The collections of the department contain a complete set of models illustrating problems in projections and descriptive geometry, as well as the usual charts, blue prints, and models for use in the lecture and drafting rooms. A special feature of the collection is a full set of Olivier models illustrating the warped surfaces and problems in intersections and tangencies.

1, 2—Drafting. 1 hour and 14 hours drafting. Professors MAYER, MILLER and HARRINGTON, and Mr. BEANS.

(*a*) Elements of mechanical drafting—Use of instruments; plane problems; free hand lettering; dimensioning; (*b*) Projections—Orthographic projection; intersections; developments; problems in descriptive geometry; isometric projection; cabinet projection; (*c*) Machine drafting—Conventional signs for materials of construction; sketching of machine details. Working drawings; tracings; blue printing; (*d*) Topography—Conventional signs; hill shading; mapping.

3, 4—Descriptive Geometry. 3 hours. Professors MAYER, MILLER and HARRINGTON.

Problems on point, line, and plane; classification of surfaces; tangent planes to single curved surfaces and surfaces of revolutions; intersections; developments; warped surfaces.

5, 6—Drafting. 6 hours. Professors MAYER and MILLER.

(*a*) Graphics—Shades and shadows; perspective; (*b*) Stone cutting—Buttress; wing-wall; arches.

Pre-requisite: Drafting 1-2, 3-4.

7, 8—Drafting. 6 hours. Professors MAYER, MILLER and HARRINGTON.

(*a*) Structural drafting—Standard rolled sections; conventional riveting signs; standard connections; methods of framing and detailing structural work; beams; columns; plate girder; roof trusses; bridge details; (*b*) Machine drafting—Working drawings; tracing and blue prints of machine details; boiler and engine-room layouts, etc.

Pre-requisite: Drafting 1-2, 3-4.

ECONOMICS

2—3 hours. Professors SEAGER and AGGER and Dr. ANDERSON.

Introduction to Economics. Lectures, reading and text-book discussion. In this course the fundamental principles of economics are studied with particular reference to their application to current economic and social problems in the United States, and with special regard to the needs of students in engineering. Third-year students in Electrical and fourth-year students in Mechanical Engineering.

ELECTRICAL ENGINEERING

2—Elements of the Dynamo. 2 hours. Professors ARENDT and MORECROFT. (1 quiz period for E. E. students.)

A general consideration of the principles and parts of Dynamo Electric Machinery. History, definition of dynamo and motor, reversibility of functions, magnetic field, magneto-motive-force, hysteresis, elementary dynamo, generation of e-m.f., collector rings and commutator. Parts of the dynamo; the magnetic circuit, materials and function. The armature core: materials, eddy currents, forms, construction. The armature winding, material, function, multiplication of electro-motive-force, types. The commutator: materials and construction. Brushes: function, materials and supports. Field frame: materials, forms, development of magnetic flux, windings, magnetic leakage. Armature reaction: cause of, back and cross ampere turns, brush shifting, sparking at brushes and remedies. Action of different types of dynamos, and typical forms. Text-book: Crocker's *Electric Lighting*, Vol. I.

Pre-requisite: **Physics 3-4 and 5.**

4—Electric Distribution. 2 hours. Professor ARENDT.

Principles and Methods of transmitting, distributing and controlling direct currents. Introductory, direct current series and parallel systems, feeders and mains, voltage regulation, networks, high tension d.c. systems.

Principles of alternating currents, self and mutual inductance, capacity, impeddance, effective values of current and voltage, phase angle and power factor. Text-book: Crocker's *Electric Lighting*, Vol. II.

For E.M., C.E., Met.E., Chem.E. and San.E. students.

52—Design of Direct-Current Machinery. 2 hours and 1 afternoon. Professor ARENDT.

Application of electrical and mechanical theory to the design and calculation of D. C. machinery with complete and original designs of generators or motors in accordance with specifications, requiring all calculations and working drawings. Reference books: Thompson's *Design of Dynamos*, Cramp's *Continuous Current Machine Design*.

Pre-requisite: Phys. **5** E. E. **2** and **101**. Parallel course: E. E. **173-174**.

54—Design of Alternating-Current Machinery. 2 hours and 1 afternoon. Professor SLICHTER.

The application of alternating current theory and practical data to the calculation and design of alternators, transformers, induction motors and other alternating current apparatus. Reference books: Arnold's *Wechselstromtechnik;* Thompson's *Dynamo Electric Machinery*, Vol. II, and McAllister's *Alternating Current Motors*.

Pre-requisite: E. E. **52, 103** and **105** and Mechanics **108**. Parallel course: Mechanics **110** and E. E. **175-176**.

72—Direct-Current Laboratory. 1 hour and 1 afternoon. Messrs. HEHRE, MASON and KELLER.

Short Course for students in Mining, Metallurgical, Civil, Chemical Engineering and Chemistry. The experiments cover the following: Fall of Potential, Resistance determinations, Study of various types of D. C. generators, their connections and characteristics of operation. Working of generators in parallel. Study of various types of motors, their connections, characteristics of operation and determination of commercial efficiency by brake tests. The results of these experiments are handed in as reports which are returned promptly to the students, with comments and corrections. Text-book: Morecroft and Hehre: *Short Course in Electrical Testing*.

Pre-requisite: Phys. **5, 43** or **44** and E. E. **2**.

73—Direct-Current Laboratory Work. 1 afternoon. Mr. HEHRE.

Short course for students in Mechanical Engineering. Same as **72**.

Pre-requisite: Phys. **5, 43** or **44** and E. E. **2** with parallel course E. E. **101**.

75—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Messrs. HEHRE, MASON and KELLER.

Short course for Mining and Mechanical Engineering students. The experiments cover the following: Study of Elementary phenomena of alternating current circuits, with determination of inductance, capacity, impedance, true watts, apparent watts and power factor. Study of an Alternator, its operation, characteristic curves and wave form. Transformers: Their operation and commercial efficiency. Induction motors: Characteristics and efficiency by brake tests. Synchronous motors, their operation under various conditions and characteristic curves. Rotary converters, operation under various conditions of load and power factor (direct and inverted). Alternators in parallel, division of load and conditions for maximum economy. The student is required to prepare a report upon each experiment which is promptly corrected and returned to him for his instruction. Text-book: Morecroft and Hehre.—*Short Course in Electrical Testing.*

Pre-requisite: E. E. 72 or 73 and 4 or 104.

76—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Messrs. HEHRE, MASON and KELLER.

Short course for Civil Engineers. Same as 75.

Pre-requisite: E. E. 4 and 72 or 73.

98—Thesis. Original investigation of and report on some problem of Electrical Engineering, approved of by the head of the department. Optional.

101—Generator and Motor Practice. 3 hours. Professor SLICHTER and Mr. HEHRE.

A course of lectures parallel to and descriptive of D. C. laboratory work. Short circuits and protective devices. Instruments: construction and use. Armature: e. m. f. current, resistance of, voltage drop in, windings and connections. Commutator: function, construction, heating, sparking, collecting brushes and holders. Magnetic circuit: calculation of flux and field windings. Heating of field and armature. Characteristics of the various types of generators and methods of regulation. Motors, theory of action and types. Methods of control and speed regulation. Losses and determination of efficiency by brake, stray power and pumping back methods. Text-books: Crocker's *Electric Lighting,* Vol. I, and Sever-Townsend's *Laboratory and Factory Tests in Electrical Engineering.*

Pre-requisite: Phys. 5 and E. E. 2.

103—Electric Motors. 3 hours. Professor ARENDT.

(For E.E.) Electric motors, their action, control and application. Introductory. Classification of work requirements. Shunt Motors: Characteristics, predetermination of action, and efficiency, methods of speed control and regulation, rheostatic, field weakening, multiple voltage, double armature and teaser system. Series Motors: Connections, predetermination of characteristics and efficiency, control: rheostatic, field weakening, double armature and series parallel. Compound motor, characteristics and methods of control. Alternating current motors introductory. Commutator A. C. motors, series and repulsion types, characteristics and control. Synchronous Motors, characteristics and control. Induction Motors, single and polyphase, characteristics, methods of starting, speed control and regulation. Electric Drive, advantages of and application to machine tools, cranes, elevators, presses, pumps, fans, wood working and mill work. Text-book Electric Motors by Crocker and Arendt.

Pre-requisite: E. E. 104, 173 and 174. Parallel course: E. E. 175-176.

103A—Electric Motors. 2 hours. Professor ARENDT.

Electric Motors, their action, control and application. 103 abridged for Mechanical Engineering Students.

Pre-requisite: E. E. 4 and 73. Parallel course: E. E. 75.

104—Electric Distribution. 3 hours. Professor SLICHTER.

Principles and methods of transmitting, distributing and controlling direct and alternating currents. Introductory, Physical properties of conductors, direct-current series and parallel systems of distribution, feeders and mains, voltage regulation, three-wire systems, high voltage direct-current systems, network systems.

Principles of alternating currents, study of wave shapes, inductance, capacity, phase angle, effective values of electromotive force and current, power factor, resonance, simple circuits, parallel circuits, line inductance and distributed capacity, calculation of single phase circuits. Text-book: Crocker's *Electric Lighting*, Vol. II. For third year E. E. and M. E. students.

Pre-requisite: Phys. 5 and E. E. 2.

105—Alternating-Current Engineering. 3 hours. Professor SLICHTER.

Electric power systems, including translating, controlling and transmitting equipments. Constant potential and constant current transformers, principles, efficiency, regulation and protection. Polyphase systems of generation, two phase and three phase, economy of generators, of transmission, and conversion from one system to another. Calculation of alternating current transmission lines, regulation of voltage and power factor of systems. Switch-boards, materials, apparatus used upon, location and types. Line construction and protection, pole lines, cable and conduit systems. Text-book: Steinmetz's *Electrical Engineering*.

Pre-requisite: E. E. 101 and 104. Parallel course: E. E. 175-176.

105A—Alternating-Current Engineering. 2 hours. Professor SLICHTER.

105 abridged for Mechanical Engineering students.

Pre-requisite: E. E. 4 and 101. Parallel course: E. E. 75.

106—Electric Plants. 2 hours. Professors SLICHTER and ARENDT and special lecturers.

Management of electric plants and industrial enterprises. Electric illumination, methods of charging for electric power, operating expenses, sources of income, organization and administration of corporations, reports, specifications, contracts, insurance regulations, patents and statistics.

Pre-requisite: E. E. 104 and 105.

108—Plant Inspection. 3 hours. Professors SLICHTER and ARENDT.

Pre-requisite: E. E. 104, 173-174. Parallel course: E. E. 105 and 106.

109-110—Telegraphy and Telephony. 1 hour. Professor ARENDT.

The principal methods and instruments employed in telegraphy, telephony and electric signalling. Telegraphy: Historical review, Morse systems, relays and sounders, earth circuits, station equipments, repeaters, differential and polarized relays, duplex systems, quadruplex systems, telegraphy from moving bodies, recording systems, submarine cables and telegraph circuits. Wireless telegraphy: Generation of electrical waves, simple transmitting and receiving apparatus. Telephony: Historical review, Bell's work, the magneto-telephone, the microphone and carbon transmitters, use of induction coils, call methods, series and parallel circuits, subscriber's equipment, line disturbances, common battery systems, subscriber's and exchange equipment, party lines, automatic systems, combined telegraphy and telephony. Text-books: Maver's *American Telegraph Practice* and Miller's *American Telephone Practice*.

Pre-requisite: E. E. 104.

112—Electric Railway. 2 hours. Professor SLICHTER.

Special instruction in calculation, installation and operation of electric railway systems. Historical review and early development. Train resistances due to tracks and bearing surfaces, curves, grades, and air. Acceleration and breaking. Speed time curves. Motors for railway work. Controllers. Distribution systems, track construction, bonding and electrolysis. Trucks, wheels and car bodies. Conduit, storage battery and third rail systems. Electric locomotives and multiple unit control. Testing railway equipments. Financial considerations.

Pre-requisite: E. E. 104 and 173-174.

112A—Electric Railway. 2 hours. Professor SLICHTER.

112 abridged for Civil Engineers.

Pre-requisite: E. E. 4 and 72. Parallel course: E. E. 76.

173-174—Direct-Current Labratory. 6 hours (2 afternoons). Messrs. HEHRE and KELLER.

1. Practice in the accurate use of voltmeters and ammeters for the measurement of electromotive force and current. Determination of resistance of the electrical circuits of electrical machinery by "drop," comparison and direct deflection methods. Use of Wheatstone bridge for determination of high resistance. 2. Generators: Preliminary study to bring out relations between speed, field strength and voltage. Operation of shunt, series and compound-wound generators with determination of characteristic action of each type. Distribution of potential around commutator and distorting effects due to armature reaction. 3. Motors: Function and operation of starting boxes, study of motors, existence and measurement of c.e.m.f., operation of shunt, series, compound and differentially wound motors, determination of speed-load curves of each type. Efficiency tests by brake and prediction methods. 4. Operation of shunt and compound-wound generators in parallel, methods of connecting, distribution of load, effects of individual differences, etc. 5. Heat runs, to determine load capacity and efficiency of generators and motors by "pumping-back" tests. 6. Tests on constant current arc generators, series boosters, balancer sets, three-wire machines, series-parallel control of railway motors, etc

Pre-requisite: Phys. 5, 43 or 44 and E. E. 2. Parallel course: E. E. 101.

175-176—Alternating-Current Laboratory. 1 hour lecture and 6 hours laboratory practice (one whole day) first term, 1 hour lecture and 6 hours laboratory practice (2 afternoons) second term. Professor MORECROFT.

1. Alternating current circuits; determination of inductance, capacity, impedance, phase relations, true and apparent watts and power factor. 2. Alternators; operation at different power factors, magnetization curves, determination of losses and synchronous impedance, field compounding, etc. 3. Alternators in Parallel: division of load, cross currents and adjustment of excitation for maximum economy. 4. Synchronous Motors: Methods of synchronizing, efficiency, action under varying conditions of load and field current. 5. Rotary converters: Methods of starting, operation direct and inverted, compounding, determination of voltage ratios regulating pole rotary and determination of efficiency. 6. Transformers: operation, determination of losses, regulation, heating and efficiency. Use as induction regulators and phase changers. 7. Wave Forms: determination of wave shapes and phase relations of electromotive-force and current in relative and non-relative circuits as well as in the primary and secondary circuits of transformers by instantaneous contact and oscillograph methods. 8. Resonance: by means of inductance and capacity in series, by inductance and leading current produced by synchronous motors, with application to transmission lines and rotary converter regulation. 9. Induction Motors: methods of starting, characteristic curves, determination of losses and efficiency by brake tests, application of circle diagram and use as frequency changer. 10. Induction Generator: operation and determination of the external characteristic. 11. Single-phase commutator motors, comparison of operation on a.c. and d.c. circuits; predetermination of characteristics by diagram. 12. Study of mercury arc rectifiers with curve analysis by ondograph and oscillograph. Text-book: Morecroft's *Laboratory Manual for Alternating Currents.*

Pre-requisite: E. E. 104 and 173-174. Parallel courses: E. E. 103 and 105; Mech. 109 and 110.

177—Instrument Laboratory. 1 hour and 2 afternoons. Mr. MASON.

1. Calibration of ammeters by comparison with laboratory standards. Kelvin balances, Siemens' dynamometers, and potentiometers. 2. Calibration of voltmeters. 3. Calibration, adjustment and determination of constants of A. C. and D. C. watt-hour meters, by various methods. 4. Determination of resistances: by Wheatstone bridge and potentiometer methods. 5. Measurements of Inductance and capacity. *a.* By comparison with standards using A. C. bridge. *b.* By absolute method, including determination of constants of ballistic galvanometer. 6. Magnetic measurements. Determination of coefficient of magnetic leakage of generator or motor. Determination of the permeability of samples of iron and steel. *a.* By Hopkinson's method. *b.* By Ewing double bridge method. *c.* A. C. voltmeter

method. *d.* Direct reading voltmeter method. Determination of Hysteresis by Hopkinson's Double bridge. Voltmeter and Ewing tester methods. 7. Storage Battery Testing. Determination of normal rate of discharge, capacity and efficiency at normal rates, capacity at various rates. Constant current and constant potential methods of charging, weight efficiency and losses on standing. 8. Photometry. *a.* Proving gas meters and determination of candle power of gas against standard candles. *b.* Candle power incandescent lamps using standard candle. *c.* Distribution of light from an incandescent lamp, using secondary standard. *d.* Determination of mean spherical and mean hemispherical candle power of an incandescent lamp. *e.* Relations between voltage, candle power, efficiency and life of incandescent lamps. Arc lamp photometry. 9. Cable Testing. *a.* To determine insulation resistance; induction and capacity. *b.* To determine location of faults.

Pre-requisite: E. E. 173-174.

Graduate Courses

101, 104 and 173-174—Dynamo and Motor Practice, Electrical Distribution and D. C. Electrical Laboratory. 3 hours lecture and 6 hours laboratory.

Pre-requisite: Phys. 5, 43 or 44 and E. E. 2.

175-176—Alternating-Current Laboratory. With Mechanics 109 and 110. 5 hours first half-year, 4 hours second half-year and 2 afternoons.

Pre-requisite: E. E. 104, 173-174, and Mechanics 108.

103, 105, 106, 175-176—Electric Motors, Alternating Current Engineering and Electric Plants, and Electrical Laboratory. 7 hours, 2 afternoons first half-year; 3 hours, 2 afternoons second half-year.

Pre-requisite: E. E. 104, 173-174.

GEOLOGY

4—Petrography. 2 afternoons two months of the second half third year. Professor Berkey.

A short course in the microscopic study of rocks.
Pre-requisite: Mineralogy 6.

5-6—General Geology. 3 hours lectures, second year. Professors Kemp, Grabau and Berkey.

First half-year physical geology, with practical work in the rock collections under the lithological part of the subject; second half-year, stratigraphical and historical geology, involving laboratory work with index fossils and collections illustrating the geology of the United States. Text-books: Kemp's *Hand-book of Rocks;* Scott's *Introduction to Geology.*
Pre-requisite: Mineralogy 1-2.

16—Index Fossils. 1 hour lecture, 8 hours laboratory, second term. Professor Grabau and Mr. Hintze.

A study of the invertebrate fossils characteristic of the various geologic horizons of North America.
Pre-requisite: Geology 5-6.

18—General Geology. Professor Berkey.

A general discussion of dynamical, structural and historical geology, with practical work in the rock collections and assigned field work on Saturdays during the last six weeks. Special course during the second half-year for students in Civil Engineering only.
Pre-requisite: Mineralogy 5.

20—Rocks and Soils. 2 hours lectures and recitations, second term. Professor BERKEY.

A study of the residuary products from rock decay; types of soils; soil classification and mapping. Open to students who have completed a course in general geology.

51—Principles of Geology. 2 lectures per week. Professors GRABAU and BERKEY.

Principles of the formation of sedimentary deposits, involving a discussion of marine and continental sedimentation, the criteria by which various sediments can be recognized, methods of preservation of organic remains, and the principles of geographic and geologic distribution of organisms. Principles of correlation. Text-book: Grabau's *Principles of Stratigraphy.*

Pre-requisite: Geology **6** and **18.**

52—Principles of Geology. 2 lectures per week, second term. Professors GRABAU and BERKEY.

A discussion of secondary structural features; and of formation of folds, faults, etc. Vulcanism, metamorphism, secondary mineralization.

Pre-requisite: Geology **6** and **18.**

101—Applied Petrography. 2 hours lectures and 1 afternoon laboratory work. Professor BERKEY.

Interpretation of rocks based on microscopic study. Rock origin, history, and present condition. Problems connected with ore deposits. Special course first half-year for students in Mining Engineering.

105-106—Economic Geology. 3 hours lectures and one elective conference, third year. Professor KEMP.

First half-year, discussion of the general features and formation of ore bodies, followed by a description of the deposits of the ores of iron, copper, lead, zinc, silver, gold, and the lesser metals, with especial reference to North America; second half-year, a description of the distribution and occurrences of coal, petroleum, natural gas, asphalt, building-stone, water supply, salines, and minor minerals. Text-book: Kemp's *Ore Deposits of the United States and Canada,* and lecture notes privately printed.

Pre-requisite: Geology **5-6.**

107-108—Invertebrate Palæontology. 2 hours lecture and 4 hours or more laboratory. Professor GRABAU and Mr. HINTZE.

First part of the course deals with the principles of palæontology; methods of study of the ontogeny of hard parts of animals, and the laws of morphogenesis. This is followed by a consideration of the classes of invertebrates important from a palæontologist's point of view, emphasis being laid on the features which show genetic relationship. Special attention is given to groups whose evolution has been worked out. Text-book: Zittel-Eastman, *Text-book of Palæontology,* Vol. I.

110—Geological Examinations and Surveys. 2 hours, second half fourth year. Professor KEMP.

A discussion of the methods of systematically recording and interpreting geological phenomena, with illustrations drawn from experience in mining and other branches of engineering; and of the organization and scope of geological surveys on a larger scale. This is followed by a sketch of the history and results of state and national geological surveys in this and other countries; and of other sources of detailed information regarding local geology.

Pre-requisite: Geology **105-106.**

112—Field Geology. All the officers of the Department.

A summer course of a week or ten days near New York for students in the course of Mining Engineering. Graduate students in the department may join the party. Instruction is given in the field in observing, recording, and interpreting geological phenomena and in the preparation of maps and sections. A written report is required.

201-202—Petrology. 2 hours lectures and 4 hours laboratory, fourth year. Professors KEMP and BERKEY.

A discussion of the origin, microscopic structure, and mineralogical composition of the crystalline rocks, and of metamorphism.

Pre-requisite: Geology 4.

LAW

Business Law. 3 hours. Professor KIRCHWEY and Mr. WHITAKER.

A discussion of the elementary rules of law governing business transactions, including real property, contracts, agency, commercial paper, sales, suretyship, bailments, torts, partnership, corporations. The rules of law are developed and illustrated by examples taken from the law reports, and dealing with situations such as engineers have in fact met and are apt to meet in the practice of their profession.

MATHEMATICS

1—Algebra. 2 hours. Professors FITE, HAWKES and GROVE, Mr. SICELOFF, Dr. REDDICK and Dr. LENNES.

Includes such topics as determinants, complex numbers, the theory of equations and partial fractions. First term.

Pre-requisite: Entrance Mathematics.

2—Algebra. Professor HAWKES and Mr. GRAVES.

Equivalent of 1. Second term.

3—Analytical Geometry. 3 hours. Professors FITE and HAWKES, Mr. SICELOFF and Dr. LENNES.

Introduction to algebraic geometry, dealing with such topics as co-ordinate systems, transformations, loci and their equations, the straight line, circle, parabola, ellipse, hyperbola, the geometric interpretation of the general equation of second degree, and the elements of three-dimensional geometry. First term.

Pre-requisite: Entrance Mathematics.

4—Analytical Geometry. Mr. GRAVES and Dr. REDDICK.

Equivalent of 3. Second term.

64—Calculus. 5 hours. Professors MITCHELL and FITE, Mr. SICELOFF, Dr. REDDICK and Dr. LENNES.

An introduction constituting with 65 (see below) one course in the calculus. Differentiation of algebraic and transcendental functions, with applications to geometry, maxima and minima and mechanics. Second term.

Pre-requisite: 3 (or 4).

65—Calculus. 5 hours. Professors KEYSER, FISKE, MACLAY, MITCHELL, FITE, Dr. GROVE and Dr. REDDICK.

Continuation of 64. Further study of the differential calculus; the principles of the integral calculus; applications to geometry, physics and mechanics. First term of second year.

Pre-requisite: 3 (or 4), and 64 (or 67).

67—Calculus. Professor GROVE and Dr. LENNES.

Equivalent of 64. First term.

68—Calculus. Professor GROVE and Dr. LENNES

Equivalent of 65. Second term.

MECHANICAL ENGINEERING

11-12—Steam Power Machinery. 3 hours, with 1 afternoon in the second half year only. Professors LUCKE, PIGOTT and PARR.

Functions, Forms and Principles of Operation of the Typical Steam power Plant Units, Auxiliaries and Connecting Elements—Methods of receiving, storing and firing coal, coal handling machinery, grates, stokers and furnaces for the combustion of coal; smokeless combustion and smoke ordinances; flow of gases through boilers, flues, dampers and the generation of necessary draft by chimneys, fans and steam jets. The construction and operation of boilers, boiler settings and foundations. Methods and apparatus for feeding water to boilers, necessary boiler attachments and trimmings. Flow of steam from boilers to engines and the grouping of engines and boilers, piping, valves, fittings and pipe covering. The heating of boiler feed water in feed water heaters and economizers. Purification of boiler feed water and effects of impure water on the boiler. Boiler strength tests and inspection laws. Boiler explosions. Steam pipe condensation and drainage. Steam traps, separators, steam superheating and superheaters. Condensing operation of steam engines by jet, surface, ejector and barometric condensers. Necessity for and types of circulating, hot-well and dry vacuum pumps and cooling towers. Typical steam engines and the variations in form and character of their important parts. Engine valves of simple and complete form, relation between construction of engine and valve gear to its economy. Special valve gears for high economy, for reserving and for power control. Regulation of engines and engine governors. Relation between engine construction, foundations, vibrations and balancing. Steam turbines. Typical steam plant arrangements for various special and standard conditions.

Second year mechanical and third year chemical engineering students.

Pre-requisite: Physics 3-4.

13-14—Steam Power Machinery. 3 hours. Professors LUCKE and PIGOTT.

Short course adapted from M. E. 11-12. Second year Civil and Electrical; Third year Metallurgical and Mining Engineering.

Pre-requisite: Physics 3-4.

17-18—Engineering Thermodynamics. 2 hours. Professor LUCKE and Mr. THURSTON.

Laws of Heat Generation by Combustion, Heat Transfer and Transformation into Work—Relation between temperatures and quantities of heat. Units of heat. Effect of heat on solids, liquids, gases and vapors. Laws of heat transfer. Laws of surface evaporation, ebullition and condensation. Properties of saturated and superheated vapors. Combustion of fuels, calorific power, quantities of air for combustion. Temperature of combustion. Boiler efficiency and conditions affecting. Principles of chimney draft. Laws of expansion and compression of gases. Work and heat diagrams to pressure volumes and temperature entropy co-ordinates. Air and wet vapor compression. Expansion of steam by hypothetic, adiabatic and saturation laws and application to steam engine efficiency. Missing water in steam engines. Influence of cylinder condensation, re-evaporation, steam jackets, initial superheat, compounding and reheating on steam engine efficiency. Relation of boiler and engine performance. Free expansion laws and application to injector and steam turbine nozzles. Heat transformation by perfect gases. Hot air, gas and oil engine efficiency. Mechanical refrigeration. Effects of evaporation of ammonia and carbonic acid and expansion of air. Heat balances and combined efficiency of complex systems.

Third year Mechanical, Electrical, Civil and fourth year Chemical Engineering; Fourth year Mining Engineering for first term.

Pre-requisites: Mechanics 102; M. E. 11-12 or 13-14.

19-20—Engine Design. 3 hours and 2 afternoons. Professor RAUTENSTRAUCH.

Advanced Machine Design Based on the Thermal and Mechanical Problems Involved in the Design of a Steam Engine for Power, Economy and Regulation—Determination of ideal indicator card, probable M.E.P., piston speed, R.P.M., and displacement for required power, selection of single or multiple expansion construction from economy requirements, limits of clearance, cutoff, release, compression and admission for type of valve gear selected. Stresses due to steam and inertia in the principal parts. Forms and proportions of the parts determined by

intensity, distribution and nature of the stresses, properties of the materials and conditions affecting maintenance. Determination of proportions of engine parts. Design of fly-wheels for limiting variation in velocity and analysis of resulting angular variation. Balancing the engine. Valve gears and governors, determination of the proportions of the valve for predetermined steam distribution, analysis of valve movements and moving gear. Graphic representation of the simultaneous events of valve opening, steam velocities and piston velocities. Analysis for the effect of the angularity of the rod. Equalizing the events of the valve. Analysis of the characteristics of the shifting eccentrics and the resultant variations in the valve events. Layout of the Corliss valve gear with single and double eccentric, and proportions of the mechanism. Steam engine governors, flyball and shaft governors, limits of movement, valve gear resistance. Proportions of the governor.

Fourth year Mechanical Engineering.

Pre-requisites: M. E. 39, 40, 11, 12, 17-18.

21—Gas Power Machinery. 4 hours and 1 afternoon. Professor LUCKE and Mr. THURSTON.

Theoretical and Practical Consideration Affecting the Generation of Power by Gas Engines, Including Oil Vaporization, Coal Gasification and the Design of the Machinery—Efficiency, M.E.P., displacement per minute per I.H.P. for reference diagrams. Limitations of external and internal heating. Methods of explosive and non-explosive internal heating. Properties of explosive gas mixtures, air necessary, calorific power per cu. ft. of mixture; temperature of combustion, heat suppression, efficiency of combustion, pressure and volume effects, limitations of proportions, temperature of ignition, rate of propagation, the explosive wave. Critical examination of modern gas engine forms and functions of parts; means for mixing and proportioning, pressure regulators, ignition; governors, effects on the engine and mechanism; starting equipment;exhaust piping and muffling; effects of back pressure in the engine; cooling; preignition, effect of cooling on economy. Large blast furnace practice, methods of gas cleaning; blast furnace gas, quality. Large engine construction, and forms of parts. Producer gas practice; standard producer for anthracite and bituminous coal, characteristics; gas, variation in quality, effects on the engine; methods of blasting producers, auxiliary steam supply and steam consumption; efficiency and rate of combustion in producer; scrubbers and tar extractors. Carburetors and vaporizers for liquid fuel; petroleum distillates, crude oil and denatured alcohol, vapor tension curves for liquid fuels. Characteristics of modern forms of gasoline and oil engines, gas power plant arrangements, producer engines, their efficiency, coal consumption and comparison with steam plants.

Complete analysis of the rating, efficiency, regulation, forces acting in and strength of parts of a modern gas engine. Probable indicator card, inertia of reciprocating parts, wrist pin and turning effort diagram. Dimensions of all parts.

Fourth year Mechanical Engineering.

Pre-requisite: M. E. 19, 33.

25-26—Steam Power. 2 hours and 1 afternoon first term and 2 hours and 2 afternoons second term. Professor PIGOTT.

Relation Between the Cost of Power and Thermal Efficiency of the Plant. Commercial Value of Refinements—Determination of engine and boiler ratings and corresponding efficiencies and probable coal and water consumption for plant on given load curve. Essential relation between processes and dimensions of the steam plant. Steam plant refinements for raising efficiency of part or complete plant and relations between dimensions and effect. Use of unit costs of apparatus in estimating. examination of cost sheets to determine prime unit of cost. Cost of power. Fixed and operating charges, ratio of each individual item to total and effect of labor and fuel rates, load factor and refinements on the fractional part. Value of refinements of design on basis of capitalized annual saving by comparing the cost of waste and the cost of its elimination, including all charges. Specifications and contracts; standard and special methods and forms for defining purchaser's requirements and builder's proposals, contracts, methods of power plant erection. Designing and erecting office organization and field systems.

The work consists in laying out a simple power plant for assigned units in the drafting room or the detailing of existing general plant drawings, preparation of the bill of materials, estimating the first cost, fixed charges, probable coal, water, labor and supply cost for an assumed load curve and total power cost. The plants so designed or detailed are exchanged by students and redesigned for an increase of 100 per cent. peak and 50 per cent. mean daily load and for the maximum power cost reduction by the use of plant refinements and auxiliaries when it can be shown that additions and alterations will pay. Specifications are written for the alteration and proposals submitted.

Fourth year Mechanical Engineering.

Pre-requisite: M. E. 96S.

31-32—Standard Tests and Research Methods. 1 hour and 1 afternoon. Professor PARR.

Laboratory methods for the determination of experimental data. Derivation of physical laws from experimental results—Comparison of actual performance of machines with computed prediction and evaluation of unknown elements. Methods of approach for the solution of practical problems by experiment and computation. The work is illustrated by problems on the flow of liquids, gases and vapors, combustion, transfer of heat, steam generation and changes of state, transformation of energy, power generation and transmission, energy losses, thermal, hydraulic and mechanical. For each problem a preliminary report is submitted before the test, involving the analysis of the problem, the attempted prediction and the required test log, based on class-room explanations; this is incorporated with the tests results and an interpretation of differences between these and the prediction, including judgment of errors, to constitute the final report. The apparatus for this course includes: Pressure gauges, manometers, thermometers, pyrometers, indicators, tachometers, planimeters, barometers, weirs, channels, nozzles and orifices for water, steam and air, Pitot and Venturi tubes, steam, gas and water piping and meters, dynamometers, power scales, viscosimeters, flue gas apparatus, steam traps, hydraulic ram, steam injectors, air pump, hot air engine, duplex steam pumps, Pelton wheel, centrifugal pump, simple steam engine. Texts: *Experimental Engineering*—Carpenter, *Lecture Notes.*

Third year Mechanical Engineering.

Pre-requisites: M. E. 11-12. Courses which are parallel to it: M. E. 17-18 and Mechanics 105.

33—Standard Tests and Research Methods (Continuation of Course 31-32). 2 hours and 1 afternoon. Professor PARR.

The work of this course is the same in nature as 31-32, but the problems involve more difficult computations and more skilful manipulation of the apparatus. These problems are principally concerned with energy transformation, necessary and accidental losses and the determination of the conditions affecting performance of compound and triple expansion steam engines and pumps, operating condensing and non-condensing, with and without receivers, with and without reheaters. Hydraulic motors, one, two and three stage air compressors, with and without intercoolers, feed water heaters, fans, steam boilers, ammonia refrigerating machines, steam superheaters and condensers. Attention is also given to the commercial tests standardized by the Engineering Societies.

Fourth year Mechanical Engineering.

Pre-requisites: M. E. 31-32; M. E. 96S; M. E. 17-18.

35-36—Kinematics of Machinery. 1 afternoon. Professor THOMAS.

Determination of Paths of Motion, Velocity, Acceleration and Kinetic Forces of the Moving Parts of Machines with the Resulting Reaction Forces of the Frame—Relative motions of machine parts and the determination of the rates of motion. Determination of space, velocity and acceleration diagrams with application to the steam engine, shaper and other standard mechanisms. Construction and use of diagrams for the determination of inertia forces and their distribution in each element of a machine. The layout of motions to specifications. Design of cams with special reference to the rate of change of velocity of the moving parts and the resultant inertia forces, resistances to motion and the continuous contact of cam and follower. Analysis of link work, relative motions, inversions, adaptability to the accomplishment of specific kinds and limits of motion. Eccentrics and links for the transformation of kinds of motion; ratchet motion; running ratchets. Clutch and coupling mechanisms, connecting shafts in parallel and at an angle. Modification to permit of non-alignment. Toothed gearings. Justification of the cycloidal and involute curves in their application to gear teeth. The layout of tooth forms and the determination of the velocity ratios. Layout of bevel gear tooth forms by Tredgold's method. Approximate methods and practical rules for the layout of gear teeth. Determination of paths of contact, obliquity of motion, length of teeth, interferences in involute gearing. Determination of the necessary conditions for interchangeability in sets of cycloidal and involute gears and comparison of the system. Friction gears. Kinematics of belt drive. Open and crossed belts. Layout of belt drives and rope drives, sprocket wheels and chain drives, speed changing devices using wrapping connections. Text: *Kinematics of Machinery*—Durley.

Second year Mechanical and third year Electrical Engineering.

Pre-requisites are Math. 3-4 35 must parallel 59, 59 Pre-requisite for 36.

37—Machine Design. 1 hour, 2 afternoons, first half-year. Professor RAUTENSTRAUCH.

Adapted from M.E. 39-40.

Fourth year Chemical Engineers.

Pre-requisite: Drafting 7.

39-40—Machine Design. 3 hours, 1 afternoon, first half-year, 3 afternoons, second half year. Professor RAUTENSTRAUCH.

Analysis of stress in machine parts of standard form under varying conditions of service and the proportions of the machine elements to safely resist the resulting stresses—Application of the principles of Kinematics, Resistance of Materials, Design of Machine Elements, Shop and Foundry Methods to the design and analysis of complete machines. Examination of machines to determine the nature and distribution of the forces acting on and the resulting stresses and strains in each element due to kinetic and structural conditions. Selection of working stresses for machine parts subject to steady, repeated and reversed stresses. Selection of materials for machine parts based on their adaptability to the service and to the shop processes by which the part must be made. Determination of the proportions of machine parts subjected to tension, compression, and shear; bending and torsion; combined bending and tension, bending and torsion, torsion and compression, buckling action, and stresses due to eccentric loading and complex supports. Illustrated in the design of crank shafts, machine frames, housings and connecting rods. Gear wheels, pulleys, flywheels, springs, riveted joints, thin and thick cylinders, braces and stays, flat plate members, pressure joints, screws, belting, rope and chain drives for power transmission. Bearing surfaces, flat, cylindrical, pivot, ball, roller, thrust. Application of theory of elasticity to the more complicated elements. Grouping of machine elements into machines for functional operation, erection, adjustment, maintenance and repair and modifications demanded by facilities for manufacture. Design of machines to specification, with particular reference to modern requirements. Text: Spooner's *Machine Design.*

Third year Mechanical Engineers.

Pre-requisites: M. E. 35-36. Must parallel C. E. 53.

41—Machine Design. 1 hour and 1 afternoon. Professor THOMAS.

A short course adapted from M. E. 39-40.

Fourth year Civil and third year Electrical Engineering.

Pre-requisites: C. E. 53 for C. E. Must parallel C. E. 53 for E. E.

45 or 46—Water Power Machinery. 3 hours. Mr. HERRICK.

Principles of Design and Economy of Operation of Turbine Wheels and Water Power Plants—Action of water on curved vanes, forces developed and effect of impact, work done; centrifugal action. Theory of reaction turbines. Vane form and arrangement; total work done for axial, radial and mixed flow wheels; dependence of velocity of flow on speed of rotation; losses of energy due to friction in guide passages, wheel buckets and sluice, shock, leakage, residual velocity. Design of reaction turbines; relation between pressure and velocity of flow; methods of determining passage areas; radii of wheels, width and depth of buckets, number and thickness of vanes. Axial turbines, characteristics, forms and dimensions. Impulse turbines; essential principles and theory, advantages, ventilation of bucket, velocity of flow, available energy, efficiency. Axial impulse turbines, characteristics, forms and dimensions. Centrifugal action in axial flow, reaction and impulse turbines. Radial impulse turbines, inward and outward flow; forms, characteristics and dimensions. Descriptions of and experiments with turbines of various types. Existing water power plants. Modern governors for turbines; ideal action of direct acting governor and disturbing influences; essential principle of indirect acting governor; factors affecting regulation.

Fourth year Mechanical Engineering (45) and fourth year Civil Engineering (46). Pre-requisites: For Mechanical Engineering: M. E. 36, M. E. 33, C. E. 78; for Civil Engineers, M. E. 77, M. E. 78, C. E. 75.

50 or 53—Steam Turbines. 3 hours. Professor PIGOTT.

Fundamental Analysis of the Action of Steam Jets and Vanes and Its Application to the Design and Performance of Steam Turbines—Ratio of impulse to reactive force jets, effect of variation of curvature of the buckets, open and closed passages. Flow of steam through nozzles and turbine passages, volume, pressure, temperature, quality, weight, velocity and kinetic energy relations. Centrifugal

effect of steam moving in a curved path. Study of the use of steam in varying types of turbines. Graded pressure turbines, graded velocity turbines, mixed impulse and reaction turbines. Practical turbines belonging to these types, and study of their detailed construction. Efficiency of different types studied by analysis of energy transformation throughout the path of steam and how efficiency is varied by design of blades, passages, nozzles, number of stages, speed, clearance, leakage and mode of regulation. Construction of turbine vanes. Disc and vane friction and critical speed. Governing steam turbines, throttling method, variable admission to one or more stages and periodic admission. Steam consumption of turbines. Book used: *The Steam Turbine*—Stodola.

Fourth year Mechanical (**50**) and Electrical Engineering (**53**).

Pre-requisites: For Mechanical Engineers, M. E. **17-18**, M. E. **31-32**; for Electrical Engineers, M. E. **17-18**, M. E. **76**.

52—Organization and Management. 3 hours. Professor Rautenstrauch.

Manufacturing Organizations and Methods of Cost Accounting—Effect of methods of manufacture and capacity on systems of management of mills and factories. Analysis of the elements of factory accounting and determination of the factors entering into the cost of production. Methods for keeping record of the cost of labor and materials in the production of specific articles. The determination of establishment charges. Interpretation of costs and use of comparative values. Determination of costs and use of comparative values. Determination of the depreciation of buildings, machinery, patterns, drawings and other assets. Organization and functions of the departments of the business. Purchase of raw material and sale of product. Utilization of scrap and waste. Methods of labor compensation. Critical analysis of the methods of accounting in representative factories. Factors affecting the cost of production. Layout of complete system of organization, forms, methods of accounting and progress of work for the factory designed in course M. E. **68**, Manufacturing Plant Design.

Fourth year Mechanical and Chemical Engineering.

Pre-requisites must parallel M. E. **68** for M. E.'s.

54—Shop Processes, Tools and Time Study. 2 hours. Mr. Halsey.

The Economic Elements in Shop Processes, Time and Power per Unit of Surface Finished or Cut and per Unit of Metal Removed with the Conditions for Most Economic Production—Processes in the shop, functional operation of machine tools and limits of economic production, time of setting, handling, forming and finishing of parts for job and repetition work in quantity. Limits of time, power and cost for finishing surfaces per sq. in. and removing per cu. in. and per lb. by hand and machine operations. Machines for performing specific operations, their functional operation, capacities, adaptability and rate of production. Conditions warranting jigs and fixtures for the production of parts in quantity and for interchangeability. Economy of portable tools, devices and methods of inspection. The selection of economic cutting conditions and analysis of recent experiments. Adaptation of economic cutting speeds to machine tools. Labor-saving devices in the pattern shop, tools and appliances used, capacity and adaptability; built-up patterns, single-piece patterns, metal patterns, comparative cost and life of each; patterns for repetition work, rights and lefts, a line of sizes, interchangeable patterns, jobbing patterns, relative economy of alternating practice. Economic production in the foundry, relative value of various methods of molding large and small parts, core making, venting, pouring and handling the work, managing the cupola. Limits of labor, power and fuel per ton of castings as affected by size and form and fraction chargeable to pattern, molding and cupola and finishing. Processes of forging, hand and machine, conditions warranting power hammers, hydraulic presses, bull-dozers, presses, dies and forming devices for the production of duplicate and standard pieces. Labor and power per lb. of forging as affected by tools, size and form of work. Heating and annealing furnaces, consumption of gas and oil, labor, power and fuel per unit annealed. Distribution of cost of machine production between different processes, power, labor, material and effect of shop or tool capacity factor on fixed charges.

Third year Mechanical Engineering.

Pre-requisites are M. E. **94S**, T. C. Shopwork and M. S. **39**.

56—Water Power Installations. 1 hour. Mr. Herrick.

Selection and Arrangement of Water Wheels, Governors and Auxiliary Appliances for Different Local Conditions, Efficiency of Wheels and Plants—Characteristic of water flow through turbine guides, nozzles and buckets, conditions warranting wheel classification, efficiency of wheels as a function of type, head, speed and part gate operation, effects of different forms of gate on efficiency, relative

value of standard patterns and special designs to suit local conditions, limits of standard dynamo speeds on wheel speeds. Water wheel governors regulation. Available head at wheels and division of total loss throughout water conductor system, relation between available water supply, possible output and perfection of development work; draft tubes, stop valves, gates, vacuum and pressure relief stand pipes, relief valves and bye-passes, water racks, anchor and frazil ice. Analysis of typical installations. Water power costs. Text: *Water Power Engineering*—Mead.

Fourth year Electrical Engineering.
Pre-requisites: C. E. 77. Parallel course: M. E. 60.

59—Empiric Design. 2 hours and 1 afternoon. Professor THOMAS.

Proportioning of Machine Parts by Empiric Methods and the Production of Shop Drawings and Sketches—Modern practice in making, recording and filing shop drawings of machine details and assemblies, bills of material and listing of standard and special parts. Use of standard conventions and interpretation of shop notes on drawings. Shop sketches and dimensions. Forms of machine parts as indicated by the nature of the resistances to be overcome and the characteristics of the material. Plain, box, and ribbed cast sections, shrinkage stresses and the probability of local weaknesses. Proportions of parts by modern empirical formulas derived from practical considerations. Limiting conditions in the use of empirical formulas. Modern practice in the proportioning of machine elements. Proportions of parts adopted by the Master Car Builders' Association, Master Steam Boiler Makers' Association, United States Government, numerous manufacturing concerns and data appearing in the transactions of the various engineering societies and engineering publications. Design of simple castings from assigned data, dies for forming simple parts in a bull-dozer and the frames and parts of simple machines having given the detailed drawing of the other parts necessary to the determination of the principal dimensions.

Second year Mechanical Engineering and third year Chemical Engineering.
Pre-requisites: Drafting 1 or 2.

60—Hydraulic Laboratory. 1 afternoon. Mr. HERRICK.

Practical Work on the Flowing of Water for the Determination of Rational Coefficients with Ordinary and Extraordinary Conditions—Flow through simple holes in plate and short tubes under low heads. Flow through convergent nozzles and needle orifice. Flow through straight pipe, elbows and joints, distribution across the cross section near bends with velocity. Flow over weirs. Variation of rectangular, trapezoidal and triangular, sharp versus dull edge, approach contractions, one side, both sides and bottom. Hook gauge measurements. Measurement of quantity flowing by Venturi tube and Pitot tube. Variation of error with type, pressure drop, and size. Loss of heads by sudden enlargement in cross section in pipes running full. Inertia and water shock. Water wheels. Variation of efficiency with speed and head, analysis of losses in nozzles, bucket and friction. Efficiency of the Hydraulic Ram Test for reliability on commercial water meters. Text: *Lecture Notes.*

Fourth year Electrical Engineering and third year Mechanical Engineering.
Parallel course: For Mechanical Engineering students, C. E. 78.
Pre-requisite for Electrical Engineering students: C. E. 77.

63—Hydraulic Laboratory. 1 afternoon. Mr. HERRICK.

Same as M. E. 60. Fourth year Civil Engineering.
Parallel: Hydraulics, C. E. 75.

64—Air Machinery. 2 hours. Mr. LONGACRE.

Structures, Adaptability and Economy of Fans, Air, Gas and Vapor Compressors, Blowing Engines, Jet Blast Apparatus and Important Applications—Convection movement of air; flow of air through orifices, ducts, pipes. Hygrometric conditions of air with temperature and pressure and condensation of moisture in compressed air. Air compressors, types and construction; work of compression, M.E.P. for single and multi stage, cylinder ratios, effects of intercooling. Volumetric efficiency of compressors, real and apparent. Discharge pipe pressure pulsations, air receivers, intercooling receivers. Air end valves, poppet, slide, Corliss and ring valves, suction and delivery, differences in type and diameter and lift. Steam end valve gears and cylinder arrangement. Constant and variable speed compressor valve gear characteristics, pressure and speed controllers and governors. Analysis of complete compressor economy tests. Dry vacuum air pumps. Blowing engines, special forms and sizes of air end valves introduced by cylinders of large diameters for low pressure air. Ammonia and carbonic acid compressors; peculiarities and methods of handling liquid in the vapor; forms and characteristics.

Multi-stage centrifugal fans and service. Analysis of efficiency tests for fans and blowers. Positive blowers. Steam jet blowers and exhausters, thermal efficiency. Application of principles to ventilation and heating, blast furnace practice, compressed air and compressed gas power transmission systems, air lift pumps and air brakes.

Third year Mechanical Engineering.
Pre-requisite: M. E. 17.

66—Elevators and Conveyors. 1 hour. Mr. Moss.

Mechanical Handling of Solid Materials by Standard Elevating and Conveying Machinery, Characteristics, Speed, Tonnage and H.P. per Ton, Computations and Adaptability to Special Service—Hand handling of materials, limits, cost and conditions warranting use of machinery. Continuous conveyors, screw, bucket, scrapers, pusher, belt and pneumatic types. Intermittent conveyors; telephers, rope and cable ways, cable cars. Loaders, unloaders, storage facilities. Skips, grab buckets, tips and tipples. Short and long hoists, friction drum hoists and direct connected. Pneumatic and hydraulic elevators for freight. Fixed and travelling cranes. Passenger elevators, rope and plunger types. Safety devices. Automatic weighers of materials; coal and ore storage systems. Excavating machine and dredges. Coal and ore-handling machinery. Railroad terminal and steamship loaders and unloaders. Coke oven chargers and dischargers. Grain handling. Special adaptation to material, such as sand, plaster, glass, cement, broken rock, coal, coke, packages, barrels, corrosive, erosive, sticky, packing, and hot materials.

Third year Mechanical Engineering.
Pre-requisite: M. E. 39.

70—Pumping Machinery. 2 hours. Mr. Nickel.

The Mechanics of Moving Liquids and Standard Machinery for Pumping—Water elevators, conditions for high efficiency and limits of use. Displacement, piston and plunger pumps; forms and functions of water pistons and plungers, pump bucket forms and limits of use, volumetric efficiency of water ends. Valves for water end, mechanical, flap, poppet, ball, annular, flat, double beat type and relation, adaptability to fluid, speed and temperature; forms of valve seats, conditions for perfect flow, piston speed and water inertia. Air chambers. Suction limitations of altitude, water temperature and absorbed gases and acceleration. Peculiarities of high pressure work, accumulators. Fly-wheel pumps, steam end characteristics, relation between steam and water diameters and displacements. Direct acting pumps, valve motion in single types, full and partial steam throw valves for simple, compound and triple use of steam. Duplex direct acting pumps, structural and operating characteristics. Economy of direct acting simple and multiple expansion pumps. Centrifugal and turbine pumps, forms and operative characteristics. High duty pumping engines, conditions for maximum duty referred to steam and coal; pumping engine tests, methods of conducting and analysis of results obtained. Typical pumping engine installations. Pulsometer pumps. Jet apparatus, injectors, ejectors and eductors, construction and duty as pumps. Water relief valves, pressure and float pump governors. Text: *Pumping Machinery*, Greene.

Third year Mechanical Engineering.
Pre-requisite: M. E. 17. Parallel C. E. 78.

72—Gas Power Machinery. 2 hours and 1 afternoon. Professor Lucke and Mr. Thurston.

Short course adapted from M. E. 22.
Fourth year Electrical and Metallurgical Engineering.
Pre-requisite: M. E. 17-18.

74—Gas Power Machinery. 2 hours. Professor Lucke.

Same as 72 except for the laboratory time.
Fourth year Mining Engineering.
Pre-requisite: M. E. 17-18.

76—Standard Tests. 1 hour and 1 afternoon. Professor Parr and Mr. Herrick.

Short course adapted from M. E. 31, 32, 33.
Third year Metallurgical, fourth year Chemical, and third year Mining.
Pre-requisite for Mining, Chemical and Metallurgical: M. E. 13-14 and M. E. 17.

SCHERMERHORN HALL

77—Standard Tests. 1 hour and 1 afternoon. Professor PARR and Mr. HERRICK.

Short course adapted from M. E. 31, 32, 33.

Third year Civil, fourth year Chemical and fourth year Electrical Engineering. Pre-requisite for Civil and Chemical Engineers: M. E. 13-14 and M. E. 17; for Electrical Engineers, M. E. 17-18.

78—Kinematics. 1 afternoon. Professor THOMAS.

Short course adopted from M. E. 36.

Third year Civil Engineering. Pre-requisite: Math. 3-4.

80—Experimental Mechanical Laboratory. 1 hour and 1 afternoon. Professor PARR.

Laboratory methods for the determination of experimental data and instruction in the operation of standard machinery. Standardization of pressure gauges, vacuum gauges, draft gauges, thermometers, pyrometers and steam engine indicators. Methods of measuring brake and indicated horsepower illustrated by the determination of mechanical efficiency of a steam engine. Correct methods for starting, stopping and operating steam engines, steam pumps, air compressors, fans and internal combustion engines. Valve setting on steam engines and direct acting pumps. Variation of steam consumption with load in a simple steam engine. Variation of horsepower to compress one thousand cubic feet of free air per minute with discharge air pressure. Variation of steam consumption of a direct acting pump with pumping head. Variation of gas engine and oil engine economy with load. Measurement of water flow by means of weirs, venturi meters, pitot tubes, orifices, recording water meters of various type and weighing tanks, and the determination of the limits of usefulness and accuracy of each method. Texts: *Power Plant Testing,* Moyer; *Lecture Notes.*

Third year Mining Engineering.

Pre-requisite: M. E. 13. Parallel course: M. E. 14.

82—Heating and Ventilation. 3 hours. Mr. OHMES.

Principles of Heat Generation Transfer and Air Movement Applied to Warming and Ventilation of Buildings—Quantities of air needed for proper ventilation, amount of heat necessary to maintain temperatures against conduction, radiation and air change losses. Heating surface and coefficients of heat transfer, grate surface, pipe and duct sizes for high and low pressure steam heating, direct and indirect, hot water and hot air systems. Air tempering, cleaning, drying, humidifying. Pipe and duct layouts. Fan computations. Exhaust steam systems, vacuum circulation. Reducing valves, air valves, water expansion tanks, thermostats, thermostatic regulation systems and important details. Efficiencies of various systems and analysis of existing installations.

Fourth year Sanitary Engineering.

94S—Shop and Factory Summer Work. Professor THOMAS.

Practical Work and Directed Study in the Shops and Drafting Rooms of Representative Manufacturing Establishments with Report—Each student is provided with a printed copy of the things to be studied and reported on in detail, of which the following is a general summary:

Machine Shop. Functional operation, characteristics and powering of machine tools, capacities, layout of shop, size of shafting, belting and motors for independent and group drive. Range of cutting speeds, feeds, depth of cut. Shape and size of tools used. Report on specific observations on time of setting work, time of forming and finishing, number of pieces turned out per hour. Facilities for handling work at the machine. Facilities for producing pieces in quantity. Hand processes for finishing and tools used.

Pattern Shop. Materials of which patterns are made and methods of treating. Machine tools used in the pattern shop arrangement, capacities, adaptability, handing and storing of material and finished product.

Foundry and Forge, Description of hand and machine tools and appliances used in the foundry and forge. Compositing and treatment of foundry sands. Methods of molding. Time involved. Methods of powering, venting and chilling, cooling and finishing, handling the cupola. Composition of the charges and mixtures. temperatures, pressures, time required to charge, to melt, to pour, cool and clean. Appliances in the forge shop. Operation of power hammers, bull-dozers, shears,

heating and annealing furnaces and hand processes of forging. Time involved in production.

Drafting Room. Standards and conventions used. Filing and marking of drawings and recording of patterns. Bills of material—parts to be made—standard parts in stock.

General Management and Organization. Methods of recording time of workmen and their time distribution over on different jobs. Paying of men, methods, rates, forms and records used. Drawing of materials used from storeroom and charging to orders.

Pre-requisite course is second year shop work.

96S—Steam Power Plant, Summer Work. Professor PIGOTT.

Report based on not less than six weeks' practical work in an Operating Power Plant, including the Output, Load Conditions, Labor and Material for Operation and Maintenance, Operating Cost per Unit and the Essential Dimensional Relations between the Various Units and Auxiliaries Producing this Result—This work is done entirely by the student in the field, his only assistance being the blank report form which is put in his hands after a brief lecture on leaving the University for the vacation.

Third year Mechanical Engineering. Pre-requisite courses: M. E. 17-18, 31-32.

97—Mechanical Apparatus for Chemical Factories. 5 hours for 10 weeks in First Term. Professor THOMAS.

Characteristics of the principal types of machinery and mechanical apparatus used by the manufacturers of chemical products, including the fundamental principles upon which their design is based, the method of operation, the selection and installation to meet given conditions of service, size and capacity of each unit, and economical arrangement of the plant. Pumping machinery; direct acting steam, simple, compound and triple expansion, belt and motor driven piston and plunger pumps. Centrifugal and turbine pumps; single and multistage, screw and rotary pumps. Jet apparatus; injectors, ejectors, steam and water jet blowers. Hydraulic presses; accumulators, heavy hydraulic apparatus. Air machinery: fans, blowers, positive blowers, turbo-compressors, piston compressors for single and multi-stage compression, intercoolers, regulating devices and unloaders. Hydraulic compressors. Blowing engines. Rotary and plunger types of vacuum pumps, air lift pumps. Refrigerating machinery; compression and absorption systems using ammonia. Dense air and carbonic acid machines. Ice making by can and plate systems. Compressors, condensers, stills, brine coolers and other units in refrigerating plants. Methods employed in the transportation of solid materials; elevating and conveying machinery, continuous and intermittent conveyors, loaders, unloaders, adaptability of system to material to be handled; hydraulic and pneumatic systems of transportation. Crushing and grinding machinery; methods employed for dry and wet processes, the handling of hard and soft materials; jaw, gyratory and roll crushers; roll, tube and ball mills for fine grinding, burr-stone mills. Separating and screening machinery; construction and operation of the types used in wet and dry processes; centrifugal and shaking screens, bolting reels. Mixing machinery for dry, plastic and wet material, mixing tanks, beating engines. Drying machinery; classification of apparatus for obtaining different degrees of dryness; construction and operation of suction apparatus, press rolls, steam driers for paper, kilns for cement, wood, pottery, by means of air currents. Humidifiers. Washing and boiling machinery; washing engines, digesters, kiers. Recording apparatus. Regulating apparatus for pressures and temperatures. Measuring apparatus for water, gas and steam, weighing machinery for solid materials. Pipe, pipe fittings, valves, conduits and ducts.

Precedes and forms sequence with Chemistry 197. Fourth year students in Chemical Engineering. Pre-requisites: M. E. 11 and 12, 17 and 18.

METALLURGY

101—General Metallurgy. 3 hours first half of term. Professor KERN.

An introduction to general metallurgy; consideration of the methods. Object of the metallurgist, and application of physics and chemistry to the extraction, and to the treatment of the commoner metals. General classification of processes. Classification of fuels, and the selection of the most suitable fuels for certain purposes. The calorific value, and the temperature of combustion, of fuels. Preparation of charcoal and coke, and the recovery and utilization of their by-products. Artificial

gaseous fuels, their preparation and metallurgical utilization. Properties of gases, and the metallurgical application of the laws of gases. Classification of furnaces, and the types of furnaces for specific purposes. Refractory materials, and their use in the construction of furnaces. Transmission of heat and the thermal efficiency of furnaces. Calculation of height, sectional areas, capacity and drafts of chimneys. Fuel economizers, and their application to metallurgical furnaces. High temperature measurements.

Third year students in Metallurgical Engineering. Fourth year students, Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4.

111—Metallurgy of Copper. 3 hours, second half of term. Professor KERN.

The production of copper, its uses, and consumption. Properties of copper and its alloys. The ores of copper, and distribution. Characteristics of ores of the principal districts. Sampling, and preparation of copper ores for treatment, and cost of different methods of sampling. General outline of the metallurgy of copper. Roasting of copper ores; purposes; chemistry; and methods of roasting. The advantages, disadvantages, and comparative cost of roasting processes. Introduction to smelting copper ores in reverberatory, and in blast furnaces. Composition, physical properties, and characteristics of furnace products; blister copper, black-copper, mattes, speiss, slag, and flue-dust. Smelting in reverberatory furnaces; construction of reverberatory smelting furnaces, their capacity and efficiency. Calculation of reverberatory furnace charges. Converting of copper matte in reverberatory furnaces. Smelting of copper ores in blast-furnaces. Calculation of blast-furnace charges. "Pyrite" or "Raw Ore" Smelting. Converting of copper matte by the Mahnes process. Apparatus required for converting copper matte. Refining of blister copper, black-copper, and cement-copper. Smelting of typical copper ores, producing ingot copper; the handling, and the disposition of the furnace products; cost of treatment.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 101.

118—Metallurgy of Copper. 1 hour. Professor KERN.

Advanced Course. Treatment of low-grade ores, and of copper-silver ores by leaching. Recovery of copper from mine-water. Utilization of furnace-gas for the production of sulphuric acid. Treatment of copper-nickel ores. Metallurgical calculations of roasting operations. Application of thermo-chemistry to roasting and smelting, and to calculations of furnace efficiencies. Purchasing of copper ores and fluxes.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111.

122—Metallurgy of Lead, Silver, Gold and Zinc. 3 hours. Professor WALKER.

Properties of lead, its compounds and alloys. Classification of ores. Production and uses of lead. Outline of the metallurgical treatment of lead ores. Smelting in the reverberatory furnaces; in the ore-hearth. Blast furnace practice for smelting lead ores. Roasting in hand and mechanical furnaces. Various pot-roasting processes and sintering machines. Smelting operations; construction of furnaces; calculation of charge; disposition, handling and treatment of by-products. Desilverization of lead bullion. Influence of impurities and elimination of same. Cupellation of rich lead alloys and ores. Treatment of Dore. Silver. Its properties, compounds, alloys, etc. Direct amalgamation of silver ores. Hydro-metallurgical processes for treatment of silver ores; Ziervogel, Patera, etc. Gold. Properties, etc. Amalgamation of gold ores. Chlorination processes. Cyaniding of gold ores; laboratory tests, and chemistry of the process; modern practice, description of existing plants. Refining and parting of gold and silver bullion. Zinc. Properties, ores, etc. Calcination and roasting of zinc ores. Retorting furnaces. Manufacture of retorts; retorting practice and chemistry of same. Refining of zinc.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 111.

128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. 1 hour. Professor WALKER.

Advanced Course. Methods of receiving and sampling different classes of ore. Purchasing of ore of varying compositions. General construction of furnaces, and design of smelting plants. Organization of smelting plants; metallurgical bookkeeping, cost sheets, etc.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 122.

131—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Manufacture of iron and steel. Blast furnace. Puddling. Cementation. Crucible process. Bessemer process. Open hearth process. Statistics. Iron and steel casting. Effect of heat treatment. Effect of mechanical treatment. Malleable cast iron. Standard specifications. Constitution of iron and steel. Relation to physical properties. Change of structure with heat and mechanical treatment. Alloy steels. Corrosion.

Fourth year students in Mining and Metallurgical and Chemical Engineering. Third year students in Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4. Pre-requisite or parallel: Metallurgy 101.

134—Metallurgy of Iron and Steel. 2 hours. Professors WALKER and CAMPBELL.

Introduction, literature, scheme of iron and steel manufacture. Definitions: iron, steel, cast iron, etc. Relations of carbon and iron. Development of the industry. The blast furnace, iron ores, fuels, fluxes, smelting practice, products. Processes for purification of pig iron. Manufacture of wrought iron and crucible steel. Puddling, charcoal hearths, fineries. Cementation, blister steel. Crucible process. Bessemer process, acid and basic. Siemens-Martin or Open Hearth process, acid and basic; fuels and regeneration. Defects in ingots and other castings. Iron and steel founding. Mechanical treatment of steel, forging, rolling. Heat treatment of steel. Heat treatment of cast iron. Malleable cast iron, cupola and air furnace. Alloy steels; nickel; vanadium; manganese; chrome; tungsten, etc. Self-hardening, high-speed steels.

Practical metallography of iron and steel. Macroscopic examination. Microscopic examination of wrought iron, pipe steel, low carbon and structural steel. Shafting, etc. Medium and high carbon, rails and tires. Tool steels. Cast irons. Comparison of good with bad material. Relation between structure and properties. Corrosion. Standard specifications. Electrometallurgy of iron and steel.

Second year students in Civil, Electrical, and Mechanical Engineering. Prerequisite: Chemistry 3 or 4 and Physics 3-4.

138—Metallurgy of Iron and Steel. 1 hour. Professor HOWE.

Advanced Course. A detailed study of the constitution of iron and steel and the effects of heat and mechanical treatment upon the constituents. Discussion of the various processes of manufacture of iron and steel, alloys steels, etc. The iron and steel industry of the United States, Germany, England, and other countries. Standard methods of testing.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 131.

141—Electrometallurgy. 1 hour. Professor KERN.

Theory of the electric current, and its application in the treatment of ores, refining of metals, and production of refractory alloys. Theory of electrolysis; determination of efficiency. The solution pressure series of the metals, and its application in the refining of copper, lead, iron, nickel, antimony, tin, zinc, gold, and silver. Electrolytic refining of copper. Electrolytic refining of lead. Treatment of anode residual. Parting of silver and gold by electrolysis. Refining of gold alloys. Electrolysis of fused electrolytes; production of aluminum; treatment of sulphide ores, etc. Electric furnaces used: for smelting ores, for refining metals, and for manufacture of refractory alloys. Efficiency of electric furnaces; cost of constructing and maintaining.

Fourth year students in Mining and Metallurgical Engineering, and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4.

148—Electrometallurgy. 1 hour conference. Professor KERN.

Advanced Course. Construction of electrolytic refineries; calculations of current, and power efficiencies. Selection of most suitable electrolyte, and most

economical current density. Labor-saving appliances. Electrolytic deposition of copper, lead, zinc, nickel, gold and silver from solutions obtained by leaching their ores. Production of solid deposits, and laws governing the same. Rôle of current density in the electrolysis of aqueous and fused electrolytes, and in the operation of electric furnaces.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy **141**.

151—Constitution and Properties of Alloys. 2 hours. Professor CAMPBELL.

Pyrometry and freezing point or cooling curves. Various types of curves and their meaning. Examples of the same. Constitution of the various binary alloys. Methods of manufacture of commercial alloys. Ternary alloys. The phase rule. Change of structure in the solid state, pure metals, alloys, bronze, brass, steel. Methods of metallographic research.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy **111**; Parallel Metallurgy **131**.

155-6—Metallography. Iron, Steel and Industrial Alloys. Six lectures and 3 or more afternoons laboratory. Professor CAMPBELL.

Methods of examination. Comparison of good and bad material; wrought iron, low carbon steel, structural steel, rail steel, tool steel, etc. Examination of brasses, bronzes, bearing metals and other industrial alloys. Relation between chemical composition, physical properties and microstructure.

Course for students in Mechanical Engineering, and for special students. Pre-requisite: Metallurgy **131** or **134**.

158—Advanced Course on Constitution and Property of Alloys. 1 hour. Professor CAMPBELL.

Fourth year students in Metallurgical Engineering.
Pre-requisite: Metallurgy **151**.

62S—Summer Course in Non-Ferrous Metallurgy. Professor KERN.

For description see page 37. 1 week field work at metallurgical plants during the summer.

Instruction for this field work will be given in five one-hour conferences during the last week in April.

Third year students in Mining Engineering.

64S—Summer Course in Ferrous Metallurgy. Professor CAMPBELL.

For description see page 37. Third year students in Metallurgical Engineering. Pre-requisite: Metallurgy **101**.

66S—Summer Course in Non-Ferrous Metallurgy. Professors WALKER and KERN.

For description see page 37. Third year students in Metallurgical Engineering. Pre-requisite: Metallurgy **122**.

82S—Summer School in Assaying. Professor HALL.

72—Metallurgical Laboratory. 10 consecutive afternoons, second term. Professor CAMPBELL and Professor KERN.

Calibration of Le Chatelier pyrometer. Cyaniding and chlorination of gold ores. Roasting of copper matte, and use of pyrometer. Desilverizing of base bullion by Parke's process. Microscopic metallography. Thermal treatment of steels.

Fourth year students in Mining Engineering.
Pre-requisite: Metallurgy **111**. Parallel: Metallurgy **122**.

171—Metallurgical Laboratory. 3 afternoons. Professors CAMPBELL and KERN.

Calibration and comparison of thermo-electric, optical and radiation pyrometers. Determination of the calorific power of fuels by the Mahler-Berthelot calorimeter. Microscopic study of metals and alloys. Thermal and mechanical treatment of steels. Roasting of copper matte, and use of pyrometer. Production of blister

copper by the reaction process. Refining of blister copper. Desilverization of base bullion by Parke's process. Cyaniding of gold and silver ores. Chlorination of gold ores. Electrolytic refining of copper and lead bullion. Fusibility of slags and refractory materials.

Fourth year students in Metallurgical Engineering. Parallel: Metallurgy 101 and 111.

172—Metallurgical Laboratory. 2 afternoons. Professors WALKER, CAMPBELL and KERN.

Special investigation in some subject or subjects in either ferrous or non-ferrous metallurgy. Subjects are similar to those noted under the head of Met. 201-202.

Fourth year students in Metallurgical Engineering.

Pre-requisite: Metallurgy 171.

173-174—Metallurgical Laboratory.

Special work along the lines indicated under the head of Metallurgy 201-202. This work is intermediate between that of Metallurgy 171 and 201-202 and is designed for those desiring to take an advanced metallurgical laboratory course without confining themselves to special research work.

Pre-requisite: Metallurgy 171.

175—Metallurgical Investigation. 1 hour conferences. Professors WALKER and CAMPBELL.

Fourth year Metallurgical Engineers. Pre-requisite: Metallurgy 122. Pre-requisite or parallel: 131, 141.

77—Metallurgical Plant Construction. Professor WALKER.

General design of metallurgical plants and problems entering into the construction of same.

Special work is assigned to each student, which is carried on under direct and constant supervision in the drafting room and laboratories. The experience gained in visits to metallurgical plants is brought into practical use.

Fourth year Metallurgical Engineers. Pre-requisite: Drafting 3-4, 7-8; Civil Engineering 53; Metallurgy 122, 64S and 66S.

Graduate Courses

81—Assaying. 2 hours, 3 afternoons. Professor HALL.

Ores and metallurgical products. Text-books: Fulton's *Manual of Assaying*. The assays included in this course are: Preliminary (reagents, etc.): lead ores; gold and silver ores; pure and impure, including galena, stibnite, arsenopyrite, blende, pyrite, tellurides, etc.; mattes and tailings; corrected assays and cyanide solutions; gold, silver and lead bullions.

Third year students in Mining Engineering and Metallurgical Engineering.

Pre-requisites: Chemistry 3 or 4 and 61 or 62; Mineralogy 1-2 or 7-8.

182—Assaying. 2 lectures or recitations. 2 afternoons. Professor HALL.

A short course covering practically the same ground as Met. 81.

Third year students in Chemical Engineering and Chemistry.

Pre-requisites: Chemistry 3 or 4 and 61 or 62; Mineralogy 1-2 or 7-8.

188—Assaying. Advanced course. Professor HALL.

For those desiring to take special work in assaying.

Pre-requisite: Metallurgy 81 or 182.

Special courses, consisting of original research, will be arranged for advanced students according to their individual needs and abilities. Most of these researches will consist of work in the departmental laboratories, but others will consist of study, and still others of work in industrial establishments.

The following list shows what subjects are suited to these courses:

201-202 (*a*)—Advanced work on some problem in general metallurgy, as for example:

In Calorimetry: Determination of the calorific power of fuels, or testing some law in calorimetry;

In Pyrometry: Determination of the temperatures of metallurgical and other industrial high-temperature operations;

On Refractory Materials: Their resistance to heat and corrosion; their tendency to slack; their contraction and expansion, etc.;

On Slags: The formation points, melting points, flowing points, and their density and viscosity when molten;

(*b*)—In the Metallurgy of Copper:

The chemistry of roasting processes, such as the elimination of arsenic and sulphur; chloridizing and sulphate roasting, etc.

The reactions of smelting processes;

Wet methods of extraction;

(*c*)—In the Metallurgy of Lead, Silver, Gold, etc.:

The pot-roasting of sulphides, and others mentioned above under (*b*);

(*d*)—In the Metallurgy of Iron and Steel:

The effect of various constituents on Iron and Steel.

The heat and mechanical treatment of Iron and Steel; effect on physical properties and microstructure.

The study of alloy steels and the effect of heat treatment.

Case hardening, etc.

(*e*)—In Electro-metallurgy: Testing electro-metallurgical principles, refining, extraction and depositing process;

(*f*)—On Alloys: The constitution and properties of alloys, embracing a microscopic, pyrometric and mechanical or physical examination with a correlation of the results;

(*g*)—In Metallography: Metallography of iron, steel, industrial alloys or metallurgical products, as mattes, slags, etc.

Pre-requisite for 201-202: Metallurgy 122, 131, 141 and 171, or equivalent.

MINERALOGY

1-2—Descriptive and Determinative Mineralogy. 3 hours lectures throughout the year, 6 hours laboratory first term, 3 hours laboratory second term. Professors Moses, Luquer and Assistants.

The elements of crystallography. The blowpipe analysis of ores and other substances. The study of the important minerals, the purpose being: 1st. Sight recognition of average specimens of all common or economically important species; 2d. Rapid determination of the less characteristic specimens by simple tests; 3d. Familiarity with economic characters.

Pre-requisite: Entrance requirements in Chemistry and Physics. Prescribed course for students in Mining.

5—The Minerals of Building Stones. 2 hours lectures and 1 afternoon laboratory. Professor LUQUER and Assistant.

Study of common species, their properties, methods of determination, and their economic effect on building stones.

Pre-requisite: Entrance Chemistry and Physics. Prescribed for students in the course of Civil Engineering.

6—Optical Mineralogy. In sections, 2 afternoons per week for first seven weeks of term. Professor LUQUER and Assistant.

Principles, apparatus, and distinguishing characters of minerals in thin sections. Consists principally in the determination of minerals in rock sections by the aid of the polarizing microscope. Supplements Courses 5 and 1-2 and is preliminary to Geology 4 (petrography).

Pre-requisite: Course 5, or part of Course 1-2, or the equivalent. Prescribed for students in Mining and Metallurgy.

7-8—Descriptive and Determinative Mineralogy. 3 hours lectures, 3 hours laboratory. Professors MOSES, LUQUER and Assistants.

Modification of Mineralogy 1. Lectures identical, laboratory work condensed. Prescribed course for students in Metallurgy.

10—Mineralogy and Crystallography. 2 hours lectures and 3 hours laboratory. Professor MOSES.

Supplementing Mineralogy 15-16 by further instruction in Mineralogy and determination of the optical and geometric constants of crystals.

Pre-requisite: Mineralogy 15-16. Prescribed for third-year students in Chemistry.

15-16—Determinative Mineralogy. 3 hours laboratory. Professor MOSES and Assistant.

Sight recognition and determination of minerals important in the chemical industries.

Pre-requisite: Chemistry A and Physics A. Prescribed for students in Chemistry and Chemical Engineering.

MINING

Undergraduate Courses

51—Excavation and Tunneling. 3 hours, third year. Professor PEELE.

Excavation of earth: tools and methods employed, support of excavations, special methods for quicksand and other water-bearing material; steam shovels and other mechanical excavators; handling and transportation of excavated material; comparative costs. Explosives: black powder, nitro-glycerine and its compounds, and other high explosives; their composition, manufacture, and use. Excavation of rock: methods of drilling and blasting mammoth blasts, submarine blasting. Railroad tunnels: methods of driving and timbering; handling and transportation of excavated material; drainage and ventilation; lining of tunnels, submarine tunnels. Mine tunnels; examples from practice; sizes, details of driving, timbering, rates of advance and costs.

Required of students in the course of Mining Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry, and Physics.

52—Boring and Shaft Sinking. 2 hours, third year. Professor PEELE.

Boring: methods and appliances for small depths and for deep boring; rod boring and cable tool or oil-well method; boring with core drills, for prospecting and other purposes; survey of bore-holes. Shaft sinking: methods and tools employed in soft material and in rock; sinking linings or drop-shafts, freezing and

other special methods of sinking in soft water-bearing formations; drainage of shafts; handling and hoisting of excavated material. Shaft timbering, walling, tubbing, and other forms of lining. Costs of shaft sinking.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51.

53—Excavation, Tunneling, Boring and Shaft Sinking. 2 hours, second year. Mr. JUDD.

A condensation of courses 51 and 52, in which attention is given only to those operations that are of special interest to the civil engineer. Excavation and transport of earth for structural purposes and railroad grading; steam shovels and dredges. Explosives. Excavation of rock; methods of drilling and blasting; submarine blasting; railroad tunnels; quarrying; testing for foundations in earth, rock and watery material; well drilling; shaft sinking by usual and special methods.

Required of students in the course of Civil Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry and Physics.

54—Exploration, Development, and Methods of Working. 3 hours, third year. Professor MUNROE.

Mineral deposits, characteristics of beds, masses, veins, and other deposits, and the irregularities and disturbances to which they are subject, as affecting the work of exploration and mining. Examination and survey of mineral properties; relation of topography to geological structure; construction of maps and sections; and tracing of probable outcrops as a guide to exploration. Prospecting by ditches, pits, and deep boring. Development; choice of methods; location of openings. Working of deposits and support of excavations; theoretical considerations, methods of breaking ground in coal and metal mining, and support of mine excavations by pillars of mineral, by timbering, by masonry, and by rock filling; methods of working applicable to deposits of different thickness, inclination, and character. Coal mining; vein mining; working of thick deposits and soft-ore bodies. Salt mining. Surface working. Hydraulic mining and gold dredging.

Required of students in the courses of Mining and Metallurgical Engineering. Pre-requisite: Geology 5-6. Pre-requisites or parallels: Geology 105-106, Mining 51 and 52. Accepted together with Mining 81 and 82, or with Mining 56 and 91, as a minor for the degree of A.M.

56—Mine Engineering. 3 hours, fourth year. Professor MUNROE.

Ventilation; air of mines; mine gases; methods of ventilation; control and measurement of air currents. Drainage: sources of mine waters; methods for the control and raising of water; dams; drainage levels. Water supply. Surface handling and transportation; arrangements for loading and unloading cars and vessels, and for storing of minerals. Mineral railroads. Common roads. Accidents to men in shafts, levels and working places; fire-damp and dust explosions; mine fires; inundations; rescue and relief of men. Mine surveying, mine maps and models. Examination, sampling and valuation of mines.

Required of students in the course of Mining Engineering. Pre-requisites or parallels: Mining 54 and 71-72, Civil Engineering 76 and 28. Accepted together with Mining 54 and 91, as a minor for the degree of A.M.

71-72—Mine Plant. 3 hours, fourth year. Professor PEELE.

Description and critical discussion of the machinery and appliances employed in the equipment of mines; design, erection and care of plant. Hoisting: engines, drums, wire rope, skips and cages, head-frames; calculation of power required and methods of equalizing the load on the engine; shaft-sinking plant, over-winding. Drainage: buckets, tanks and hand-pumps; Cornish and direct-acting underground pumps; operation of pumps by electricity, compressed air, and hydraulic power. Centrifugal pumps. Ventilation: underground furnaces, positive blowers, and centrifugal fans; theory and efficiencies of fans. Air compressors: simple and compound (stage) compression; methods of dealing with heat of compression; conveyance of compressed air in pipes; reheating; operation of machinery by compressed air; efficiencies. Machine drills; coal-mining machines or coal-cutters. Handling mineral in working places. Mine cars; arrangement and construction of tracks. Underground haulage; hand tramming; mule haulage; gravity roads; steam, compressed-air, and electric locomotives; rope haulage; efficiencies; comparison of systems of haulage.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51, 52 and 54, and Mechanical Engineering 13-14. Accepted together with Mining 73 and 75, as a minor for the degree of A.M.

73—Mine Constructions. 1 hour, fourth year. Professor PEELE.

Building-stones; bricks; limes; cements and concretes. Foundations in various soils; retaining walls; masonry and timber construction, with special reference to mine work; mine buildings; trestles; ore-bins.

Required of students in the courses of Mining and Metallurgical Engineering. Accepted together with Mining 71-72 and 75, or with Mining 81, 82 and 75, as a minor for the degree of A.M.

75—Design of Mine Plant. 4 afternoons, fourth year. Professors PEELE and KURTZ and Mr. JUDD.

The students are assigned problems in the design and construction of mine plant, in connection with the development of a mine. This work supplements the lectures on the design of mining machinery, involving reading and study, and the preparation of working drawings, covering certain portions of the plant, together with bills of material, specifications, and estimates. As these drawings are intended to accompany and illustrate in part the graduating theses or projects, the designs are made in accordance with the subjects and conditions therein assigned. The work is done under constant supervision and advice in the draughting-room.

Required of students in the course of Mining Engineering. Pre-requisite: Drafting 3-4, 7-8, Civil Engineering 53. Parallel: Mining 71-72. Accepted together with Mining 71-72 and 73, or with Mining 81, 82 and 73, as a minor for the degree of A.M.

77-78—Graduating Thesis or Project. Professor PEELE.

Mining Thesis

The subjects for the graduation theses are assigned during the third year, and are made a part of the regular course of instruction. The subject given in each case is the problem of the opening and development of a mine, supposed to be located in some well-known mining district, and for which certain definite conditions as to size and character of ore body, amount of water to be pumped, and quantity of ore to be mined, are assumed. During the summer field work in mining the student incidentally obtains data for his thesis work. This information is supplemented by study of books and technical literature. During the fourth year he decides upon the proper methods for opening, developing, and working the property; and makes estimates of the plant, machinery and capital required, the cost of working, and the probable profits. He also works out in detail certain portions of the proposed mine plant, and prepares a set of working drawings, bills of materials and specifications therefor. This work, done under the supervision of competent instructors, constitutes both a review and a series of practical applications of the preparatory studies and enables the students to discover and remedy their deficiencies, giving them confidence in their ability to work out similar problems later.

Required of students in the course of Mining Engineering. Pre-requisites or parallel: All the required courses in Mining.

80—Mill Constructions. 1 hour, fourth year. Professor KURTZ.

Installation and operation of mechanical power transmission and auxiliary machinery in works for the mechanical treatment of minerals. Dealing with shafting, bearings, pulleys, belting, rope drives, gearing, etc.

Pre-requisite: Mechanical Engineering 13-14.

81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. 4 hours, fourth year. Professor MUNROE.

The general principles and theory of dressing; preliminary operations; hand dressing; cleansing; crushing; jigging with and without preliminary sizing; slime concentration; magnetic and electro-static separation; oil and flotation processes; milling of gold ores; descriptions of typical dressing works and coal-washing plants in this country and abroad.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mineralogy 1-2, Physics 3-4, and Mechanics 102. Accepted together with Mining 54 and 82, or with Mining 82, 73 and 75 as a minor for the degree of A.M.

82—Ore-dressing Laboratory. Afternoon work for three weeks, fourth year. Professors MUNROE and KURTZ and Mr. JUDD.

Mechanical testing of ores by laboratory methods; working tests with simple apparatus; adjustment and operation of concentrating machines.

Required of students in courses of Mining and Metallurgical Engineering. Pre-requisite: Mining 81. Accepted together with Mining 54 and 81, or with Mining 81, 73 and 75, as a minor for the degree of A.M.

91—Mine Administration. 2 hours, fourth year. Professors MUNROE and KURTZ.

Administration, organization, and business management, mine accounts, and cost sheets.

Required of students in courses of Mining and Metallurgical Engineering. Pre-requisite: Mining 54. Accepted together with Mining 54 and 56, as a minor for the degree of A.M.

94—Mining Law. 2 hours, fourth year. Professor KURTZ.

General principles of real estate law. Historical review of mining laws of different countries. Federal laws, concerning locations on public lands of the United States. State and territorial mining laws.

Pre-requisite: Civil Engineering 27, Mining 54.

95—Mining Conference. 1 hour. Mr. JUDD.

(Optional.) Reading and discussion of papers by the students, on mining practice and based on data accumulated in the course of the summer work in mining.

Summer Courses

58—Summer Class in Mine Surveying is held in June, at a mine in a near locality, and lasts one week. Professors MUNROE and KURTZ and Mr. JUDD.

Pre-requisite: Civil Engineering 27.

59—The Summer Courses in Practical Mining. Professors PEELE and KURTZ and Mr. JUDD.

Held in June and July, at some mine or mines selected for the purpose, in the vacation between the third and fourth years, and lasts six weeks (for details see page 31).

Pre-requisite: Mining 51, 52 and 54, Civil Engineering 15 and 27, Mechanical Engineering 13-14, and Geology 105-106.

Graduate Courses

Special courses, consisting of personal instruction, reading and experimental investigation, will be arranged for advanced students according to their individual needs and ability. These investigations will be made at mines and dressing works either in connection with the Summer class or elsewhere as assigned, with additional work, as required, in the library and in the laboratories of the department. These courses vary in difficulty and in the amount of time necessary, according as the student is a candidate for the degree of A.M. or Ph.D., and according as he pursues mining as a major or a minor subject. The time required is governed by the rule that a course or courses should occupy about 20 hours (outside reading and study included) per week if taken as a major subject, and about 10 hours per week if taken as a minor subject. Any of the following may be offered as a minor for the degree of A.M. by students who have had the appropriate prerequisites:

101-102—**Mining and Ore Dressing.** Mining **54, 81** and **82.** 4 hours, with laboratory work and reading as required.

103-104—Mining Engineer. Mining 54, 56 and 91. 4 hours lectures and reading as required.

105-106—Design of Mine Plant. Mining 71-72, 73 and 75. 3 hours and 4 afternoons drafting-room work.

107-108—Design of Ore-dressing Works. Mining 80, 81, 82, 73 and 75, with 1 hour conference additional first half-year. 3 hours and 5 afternoons laboratory and drafting-room work.

Under the regulations for the degrees of A.M. and Ph.D. the following courses may be offered by graduate students who have had all the undergraduate courses in mining or their equivalent.

201-202—Methods of Mining. Critical study of methods used in some mining region, or for a certain class of deposits; output per man, amount of timber and explosive required, and other details affecting cost. Study of conditions as determining choice of method. Determination of loss of mineral in mining. Accidents to men.

203-204—Mining Plant. Critical study of rock drilling, or coal cutting, or hoisting, or haulage, or ventilating plant at some mine or mines. Determination of efficiency and conditions affecting same.

207-208—Ore Dressing. Critical study of some detail of the ordinary dressing methods, crushing, or screening, or classification, or jigging, or slime treatment, or dry concentration, or magnetic separation, or milling of gold or silver ores, or mechanical preparation of coal. Determination of efficiency, and of conditions essential to success.

213-214—Economic Studies in Mining. Study of existing conditions affecting the production and cost of some mineral or metal, as, for example, anthracite coal, copper, or gold.

PHYSICAL EDUCATION

A1-A2—**Physical Education.** 6 lectures on personal hygiene during January. 2 hours a week of athletics and elementary graded gymnastic exercises during the whole year, except January. Dr. Skarstrom.

B1-B2—**Physical Education.** 6 lectures on public and personal hygiene during January. 2 hours a week of athletic and gymnastic exercises during the whole year, except January. Students must report at the gymnasium office within two days after the opening of the semester and fill out cards indicating the branch of athletics in which they intend to satisfy the requirements of the course. Professor Meylan, Mr. Fette, and Assistants.

Note—Students getting a grade of B or better in Physical Education A are not required to take **Physical Education B1-B2.**

PHYSICS AND MECHANICS

Mechanics 1—Statics. 2 hours. Professor BURNSIDE, Dr. WEBB, Mr. SCHROEDER, Mr. WHITTEMORE.

Class is divided into small sections for recitations. Coplanar Statics is treated by both algebraic and graphical methods. Text: Maurer's *Technical Mechanics.*

Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 3-4—General Physics: Mechanics, Wave-Motion, Heat and Light. 3 lectures and 2 recitations. Professor WENDELL, Dr. MORSE, Mr. FARWELL, Dr. WEINRICH, Mr. SEVERINGHAUS, Mr. KENDALL, Mr. NELMS, Mr. SCOTT, Mr. BRAININ.

Mechanics—Newton's laws of motion; accelerated linear and angular motions; dimensions; systems of weights and measures; energy, work, power; transformations of energy; conservation of energy; curvilinear motion with applications; gravitation; linear and angular simple harmonic motion; pendulum; wave-motion; sympathetic vibrations; elements of hydrostatics.

Heat—Nature of heat; expansion; thermometry; calorimetry; specific heat; mechanical equivalent of heat; change of state; saturated vapors and hygrometry; continuity of state; conduction; convection; radiation.

Light—General discussion of wave-theory; reflection; refraction; total reflection; index of refraction and measurement; lenses; dispersion; spherical and chromatic aberration; optical instruments; photometry; color; fluorescence and phosphorescence; radiant energy; spectrum analysis; polarization of light.

Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 5—Electricity. 3 lectures and 2 recitations. Professor WENDELL and instructors.

Phenomena of electrostatics; capacity and condensers; electrometers; current electricity and methods of production; Ohm's law with applications; Joule's law with applications; thermo-electricity; magnetic action of currents with applications; electrical units; electro-magnetic induction; inductance.

Required of all second year students in Engineering. Pre-requisite: Physics 3-4.

Physics 43-44—Physical Laboratory. 3 consecutive hours a week throughout the year. Professor WENDELL, Dr. MORSE, Dr. WEINRICH, Mr. SEVERINGHAUS, Mr. KENDALL, Mr. NELMS, Mr. SCOTT, Mr. BRAININ, Mr. MURPHY, Mr. FRAZEE.

This course consists of quantitative experiments with reports in mechanics, light, heat, electricity, and magnetism. Methods of computation, plotting and the precision of measurements are discussed in connection with the experiments.

Pre-requisite: Physics 3-4. Parallel: Physics 5.

Physics 55—Physical Measurements. 2 hours. Professor HALLOCK.

Critical discussion of physical measurements and computations.

Pre-requisite: Physics 3-4. Parallel: Physics 5.

Mechanics 102—Mechanics. 5 hours. Professor BURNSIDE, Dr. WEBB, Mr. SCHROEDER, Mr. WHITTEMORE.

This course is a continuation of Mechanics 1, using the same text book. The class is divided into small sections for recitations. Statics is completed; centers of gravity and moments of inertia of areas treated with aid of calculus; displacement, velocity, acceleration, motions of translation and rotation, work and energy, power, efficiency, impulse and momentum are all treated with special reference to engineering problems.

Required of all second year students in Engineering. Pre-requisite: Mechanics 1, Physics 3, and Mathematics 64-65.

Mechanics 105—Thermodynamics. 2 hours. Professor WILLS.

An idea of the nature of the course may be obtained from the following topical headings: The nature of heat; thermometry; calorimetry; heat and work diagrams; the First Law; applications to gases, perfect and actual; the work of Carnot; the

Second Law; the Kelvin absolute scale of temperature; the combination of the two laws; application to the problem of change of state; the properties of saturated and superheated steam; theory of the "plug experiment"; the flow of fluids from orifices.

Pre-requisite: Mechanics 102.

Mechanics 107-108—Theory of Electricity and Magnetism. 2 hours first half-year, 3 hours second half-year. Professor WILLS.

The fundamental principles of electricity and magnetism are developed and discussed with particular reference to the bearing which they have in relation to the science of electrical engineering. The course concludes with an introduction into the theory of alternating currents.

Pre-requisite: Mechanics 102.

Mechanics 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits. 4 hours first half-year, 3 hours second half-year. Professor PUPIN.

Pre-requisite: Mechanics 107-108.

Physics 52—Conduction of Electricity in Gases. 5 2-hour lectures. Professor DAVIS.

Mathematical Physics 201—Vector Analysis and Mathematical Introduction. 4 hours. Professor WILLS.

Mathematical Physics 203-204—Partial Differential Equations of Physics. 2 hours. Professor WILLS.

Laplace's Equation; Poisson's Equation; Equation of Heat Conduction; Telegrapher's Equation; Fourier's Series; Spherical Harmonics; Bessel's Functions.

Mathematical Physics 206—Mechanics. 4 hours. Professor WILLS.

An advanced course on Mechanics developed with special reference to the general methods of d'Alembert, Lagrange, Jacobi and Hamilton.

Mathematical Physics 208—Elasticity. 2 hours. Professor WILLS.

Mathematical Physics 215-216—Electricity and Magnetism and Electro-Magnetic Theory of Light. 2 hours. Professor PUPIN.

Mathematical Physics 223-224—Recent Advances in Electrical Theory. 2 hours. Professor PUPIN.

For other courses in physics and mathematical physics the student is referred to the *Announcement of the Division of Mathematical and Physical Science.*

SHOP WORK

The shop work is done in the Macy Building, which has full modern equipment, including the best types of improved machine tools for wood working and metal working in shops that provide for groups of twenty to twenty-four students to a section.

Shop work in wood is planned to lead up to pattern making and foundry work. The equipment includes benches for joinery and pattern making with the necessary hand tools and individual speed lathes for wood turning, a motor-head speed lathe of large size, 36-inch band saw and trimmers of the most recent type. There are also available for working up stock and special projects a saw bench, surfacer, jointer, mortising machine, all of the latest type.

Shop work in metal includes foundry, forging and machine-shop practice. The foundry contains molding benches for twenty students, and necessary tools for all kinds of bench work in snap flasks, floor

molding, loam work, and the application of sweeps to the making of molds, together with melting pits for the melting of brass and bronzes and a cupola for melting cast iron. In the forge shop there are twenty forges with anvils, tools and vises, a 30-pound Bradley power hammer and a 400-pound Billings and Spencer drop-press. The machine shop contains lathes, swinging from twelve to twenty inches, planers, drill-presses, universal milling machines, and grinding machines, with examples of direct-connect motor and belt drives for each. A Jones and Lamson flat turret-lathe and a Warner and Swasey screw machine are used for demonstrating modern methods of economical repetition production. In conjunction with all the shops there is a well-equipped tool-room, the attendance record is kept by a time-keeper's recording clock, and the organization and atmosphere of a commercial shop are aimed at.

1—Wood-turning and Pattern-making. 2 afternoons. Mr. CONSTANTINE.

Shopwork, demonstrations and shop visits. The construction of typical patterns and core boxes, solid, split and piece, involving the use of bench tools and turning lathe. Second year students in Mechanical Engineering.

2—Molding and Foundry Practice. 1 afternoon. Professor SLEFFEL.

Shopwork, demonstrations and shop visits. Bench molding with type patterns, swept work in green sand and loam and molding in dry sand. Second year students in Mechanical Engineering.

10S—Machine Work. Mr. WALSH.

As below. Mechanical Engineering. Section I, three weeks in June; Section II, three weeks in September. Second year.

Pre-requisite shopwork **10s** or equivalent.

11—Machine Work. 2 afternoons. Mr. WALSH.

Shopwork, demonstrations and shop visits. Practical work with the lathe, planer, drill, shaper, milling machine, grinder and turret lathe. Assembling, erection and rigger's work. Third year students in Mechanical Engineering.

12—Forging. 2 afternoons. Professor SLEFFEL.

Shopwork, demonstrations and shop visits. Management of fire, shaping, drawing, upsetting, swaging, welding, tempering and die-forging. Work on drop and helve hammers. Second year students in Mechanical Engineering.

13-14—Machine Work. 1 afternoon. Mr. WALSH.

As above. Second year students in Electrical Engineering.

15—Forging and Foundry Practice. 1 afternoon. Professor SLEFFEL.

As above. Second year students in Civil Engineering.

16—Machine Work. 1 afternoon. Mr. WALSH.

As above. Second year students in Civil Engineering.

18S—Pattern-making, Forging, and Machine Work. Three weeks in June. Professor SLEFFEL, Mr. CONSTANTINE and Mr. WALSH.

As above. Second year students in Chemical Engineering.

ZOOLOGY

7—Sanitary Biology. 2 afternoons for 6 weeks. Professor CALKINS and Assistant.

General principles of biology. Biological activity—function, metabolism, symbiosis, etc.; special biology—unicellular animals and plants of drinking waters, causes of trouble, etc.

Pre-requisite: **Bacteriology 101.**

SCHEDULE OF PRE-REQUISITES FOR SUBJECTS UNDER THE FACULTY OF APPLIED SCIENCE

Subject	Pre-requisite
Astronomy	
105—Geodesy. (For C. E.)	Math. 64-65 (Differential and Integral Calculus)
106—Geodesy. (For C. E.)	Astron. 105 (Geodesy)
107S—Geodetic Surveying (For C. E.)	Astron. 106 (Geodesy)
Bacteriology	
101—Sanitary Bacteriology	Chem. 65 (Quantitative Analysis)
Botany	
7—Growth and Character of Timber	
Chemistry	Pre-requisite
3-4—General Inorganic	Entrance Chemistry or Chem.A.
7-8—Inorganic	Chem. 21-22 (Elementary Physical Chemistry) Chem. 163-164 (Quantitative Analysis) Chem. 83-84 (Industrial Chemistry) Chem. 101-102 (Advanced Inorganic) Chem. 171 (Organic and Sanitary Analysis) Chem. 170 (Assaying) Chem. 183-184 (Industrial Electro-Chemistry)
101-102—Advanced Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
21-22—Elementary Physical Chemistry	Chem. 3-4 (General Inorganic) Phys. 3-4 (Elementary Mechanics and General Physics)
121-122—Physical Chemistry	Chem. 3-4 (General Inorganic); 61-62 (Quantitative Analysis) Phys. 3-4 (Elementary Mechanics and General Physics) Math. 64-65 (Differential and Integral Calculus)
38—Theoretical Electro-Chemistry	Chem. 3-4 (General Inorganic) Chem. 65 (Quantitative Analysis, Inorganic) Phys. 3-4 (Elementary Mechanics and General Physics) Math. 64-65 (Differential and Integral Calculus)
23-24—Physical Chemistry	See 121-122
41-42—Organic, lectures	Chem. 3-4 (General Inorganic)
43-44—Organic laboratory	Chem. 3-4 (General Inorganic) Chem. 41-42 (Organic) or parallel
141-142—Organic, general	Chem. 21-22 (Elementary Physical Chemistry) Chem. 161-162 (Quantitative Analysis, Inorganic)
143-144—Organic, conferences	Chem. 141-142 (Organic) or parallel
149—Advanced Organic. (For Chem. E.)	Chem. 41-42 (Organic)
151-152—Advanced Organic Chem. Laboratory course.	Chem. 3-4 (General Inorganic) Chem. 41-42 (Organic—lectures) Chem. 43-44 (Organic Lab.)
61 or 62—Qualitative Analysis	Entrance Chemistry or Chem.A. *Parallel* Chem. 3-4 (General Inorganic)
65—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
66—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
161-162—Quantitative Analysis Inorganic	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)

Subject	Pre-requisite
Chemistry (*Continued*):	
163-164—Quantitative Analysis	Chem. 3-4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
167-168—Advanced Inorganic Analysis	Chem. 101-102 (Advanced Inorganic) Chem. 121-122 (Physical Chemistry)
171—Organic Analysis	Chem. 163-164 (Quantitative Analysis) Chem. 41-42 (Organic) Chem. 161-162 (Quantitative Analysis, Inorganic)
173-174—Advanced Organic Analysis	Chem. 171 (Organic Analysis) or Chem. 175 (Food Analysis)
175—Food Analysis	Chem. 41-42, 161-162
176—Chemistry of Food and Nutrition	Chem. 41 (Introductory Organic)
81-82—Industrial Chemistry, general course	Chem. 3-4 (General Inorganic)
83—Industrial Chemistry, special course	Chem. 3-4 (General Inorganic) 61 or 62 Chem. 81-82 (Industrial Chemistry) and Chem. 41 (Elementary Organic)
84—Food Chemistry	Chem. 3-4 (General Inorganic) Chem. 81-82 or 41-42
88—Industrial Chemistry, laboratory practice	Chem. 3-4 (General Inorganic) and Chem. 41 (Elementary Organic)
89—Industrial Chemistry, laboratory practice	Chem. 61 or 62 (Qualitative Analysis)
95-96—Industrial Chemistry 197—Chemical Factory Machinery and Apparatus 198—Chemical Factory Apparatus and Machines 80a—Factory Inspection and Summer Memoir. (For Chem. and Chem. E.) (Second Year) 80b—Factory Inspection and Summer Memoir. (For Chem. and without memoir for Chem. E.) (Third Year)	Chem. 3-4 Chem. 61 or 62 Chem. 41-42 Chem. 65 or Quantitative
93-94—Electro-Chemistry	
181 or 182—Practical Electro-Chemistry	Chem. 3-4 (General Inorganic) Chem. 61-62 (Quantitative Analysis) Chem. 65 (Quantitative Analysis, Inorganic)
183-184—Industrial Electro-Chemistry	Chem. 3-4 (General Inorganic) Chem. 65 (Quantitative Analysis, Inorganic)
Civil Engineering	
2—Theory of Surveying	
15—Surveying (between First and Second Years)	C.E. 2 (Theory of Surveying)
21—Highway Engineering	
23—Theory of Railroad Surveying	C.E. 15 (Surveying)
25—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
26—Surveying (between Third and Fourth Years)	C.E. 25 (Surveying)
27—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
28—Surveying (between Second and Third Years)	C.E. 23 (Theory of Railroad Surveying) C.E. 27 (Surveying)
51-52—Theory of Railroad Surveying	C.E. 15 (Surveying)
53-54—Elasticity and Resistance of the Materials of Engineering	Mech. 102 (Analytical Mechanics)
55—Standard Methods of Water Analysis 57a—Statistics and Interpretation of Water Analyses 57b—Drainage of Marshes and Lowlands	Zoology 7 (Sanitary Biology) Bacteriology 101 (Sanitary Biology) C.E. 59 (Sanitary Engineering) Bacteriology 101 (Sanitary Biology) C.E. 59 (Sanitary Engineering)
58—Masonry Structures	Mech. 102 (Analytical Mechanics) Min. 5 (Minerals of Building Stones)
59—Sanitary Engineering	Chem. 82 (Industrial Chemistry)
61—Analytical Theory of Trusses	Mech. 102 (Analytical Mechanics)

Subject	Pre-requisite
Civil Engineering (*Continued*):	
62—Graphic Statics	Mech. 102 (Analytical Mechanics)
64—Graphic Statics (abridged course)	Mech. 102 (Analytical Mechanics)
71—Surveying (between Third and Fourth Years)	C.E. 51-52 (Theory of Railroad Surveying) C.E. 25 (Surveying) Math. 64-65 (Calculus)
75—Hydraulics	Mech. 102 (Analytical Mechanics) Math. 64-65 (Calculus)
76—Hydraulics. (For E.M.) (C.E. 75 abridged)	Mech. 102 (Analytical Mechanics) Math. 64-65 (Calculus)
77—Hydraulics. (For E.E.)	Mech. 102 (Analytical Mechanics) Math. 64-65 (Calculus)
78—Hydraulics. (For Chem. E. and M. E.)	Mech. 102 (Analytical Mechanics)
85—Foundations	C.E. 58 (Masonry Structures) Geol. 18 (General Geology)
87-88—The Design and Construction of Bridges, Roofs and Buildings. (For Sanitary Engs.)	C.E. 53-54 (Elasticity and Resistance of the Materials of Engineering) C.E. 61 (Analytical Theory of Trusses) C.E. 62 (Graphic Statics)
89-90—Railroad Engineering	C.E. 71 (Surveying)
94—Design and Construction of Sewers, and River and Harbor Improvements	C.E. 75 (Hydraulics) C.E. 59 (Sanitary Engineering) C.E. 26 (Surveying)
96—Principles of Hygiene, Sanitary Science and Public Health	Zoology 7 (Sanitary Biology), Bacteriology 101 (Sanitary Bacteriology), C. E. 59 (Sanitary Engineering) 57a (Statistics and Interpretation of Water Analysis) 57b (Drainage of Marshes and Lowlands)
97—Water-Supply and Irrigation Engineering	C.E. 26 (Surveying) C.E. 59 (Sanitary Engineering)
99-100—Graduation Thesis	C.E. 75 (Hydraulics)
Drafting	
1 or 2—Elements of Mechanical Drafting	
3 or 4—Descriptive Geometry	
5 or 6—Graphics	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
7 or 8—Structural Drafting	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
Economics	
2—Introduction to Economics	
Electrical Engineering	
2—Elements of Dynamo Electric Machinery	Phys. 3, 4 and 5 (Elements of Electrical Engineering)
4—Electric Distribution (For E.M. Met.E. and C.E.) *Parallel* E.E. 72 (Direct Current Laboratory)	E.E. 2. (Elements of Dynamo Elect. Mach'y) Phys. 5
52—Design of Direct Current Machinery	E.E. 2 and 101 (Elements of Dynamo Elect. Machinery)
54—Design of Alternating Current Machinery *Parallel* Mech. 110 (Th. of Variable Currents) and E.E. 175-176	E.E. 52, 103 and 105 (Design of Direct Current Machinery) Mech. 108
72—Direct Current Laboratory *Parallel* E.E. 4 (Electric Distribution)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43 or 44 (Phys. Laboratory)
73—Direct Current Laboratory. (For M.E.) *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43 or 44 (Phys. Laboratory)

Subject	Pre-requisite
Electrical Engineering (*Continued*):	
75—Alternating Current Laboratory. (For E.M. and M.E.) (Short course)	E.E. 4 or 104 (Electric Distribution)
76—Alternating Current Laboratory. (For C.E.)	E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
98—Thesis (Optional)	E.E. 4 (Electric Distribution)
Parallel Subjects of Fourth Year	E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
101—Generator and Motor Practice	All courses
Parallel E.E. 73 *or* 173-174 (Direct Current Laboratory)	E.E. 2 (Elements of Dynamo Elect. Mach'y) and Phys. 5
103—Electric Motors. (For E.E.)	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
103A—Electric Motors. (For M.E.)	E.E. 104 (Electric Distribution) E.E. 73 (Direct Current Laboratory)
104—Electric Distribution	Phys. 5 and E.E. 2 and E.E. 101
105—Alternating Current Engineering. (For E.E.)	E.E. 104 (Electric Distribution)
105A—Alternating Current Engineering. (For M.E.)	E.E. 104 (Electric Distribution) E.E. 101 (Dynamo and Motor Practice)
106—Electric Plants	E.E. 104 and 105 (Electric Distribution)
107-108—Plant Inspection	E.E. 104 (Electric Distribution)
Parallel course E.E. 105	
109-110—Telegraphy and Telephony	E.E. 2 and E.E. 104
112A—Electric Railway. (For C.E.)	E.E. 173-174 and E.E. 104
Parallel course E.E. 76 or 175-176	E.E. 72 E.E. 4
173-174—Direct Current Laboratory	E.E. 2 (Elements of the Dynamo)
Parallel E.E. 101 (Dynamo and Motor Practice)	Phys. 5 and 43 or 44
175-176—Alternating Current Laboratory	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
Parallel Mech. 109 (Theory of Alternators and Transformers), Mech. 110 (Theory of Variable Currents), E.E. 103 (Electric Motors) and 105 A. C. Eng.	
177—Instrument Laboratory	E.E. 173-174 (Direct Current Laboratory)
Geology	
4—Petrography	Min. 6 (Optical Mineralogy)
5-6—General Geology	Min. 1-2 (Descriptive and Determinative Mineralogy) Parallel course
16—Index Fossils	Geol. 5-6 (General Geology)
18—General Geology	Min. 5 (Minerals of Building Stones) Geol. 18 (General Geology)
20—Rocks and Soils	Geol. 6 (General Geology) *or*
51—Principles of Geology	Geol. 18 (General Geology)
52—Discussion of Secondary Structural Features	Geol. 6 (General Geology) *or* Geol. 18 (General Geology)
101—Applied Petrology	Geol. 4 (Petrography)
105-106—Economic Geology	Geol. 5-6 (General Geology)
107-108—Invertebrate Palæontology	Antecedent work in Geology
110—Geological Examinations and Surveys	Geol. 105-106 (Economic Geology)
112—Field Geology	Geol. 6 (General Geology) Geol. 105-106 (Economic Geology) *desirable, not prerequisite*
201-202—Petrology	Geol. 4 (Petrography)
Law	
2—Business Law	

Subject	Pre-requisite
Mathematics	
1 (or 2)—Algebra	Entrance Mathematics
64 (or 67)—Calculus	Math. 3 (Anal. Geometry) or Math. 4
3 (or 4)—Analytical Geometry	Entrance Mathematics
65 (or 68)—Calculus	Math. 3 or 4 (Anal. Geometry) and Math. 64 or 67 (Calculus)
Mechanical Engineering	
11-12—Steam Power Machinery. (For M.E.) 13-14—Steam Power Machinery (Short M.E. 11-12) (For other than M.E.)	Phys. 3-4 (General Physics)
17-18—Engineering Thermodynamics	M.E. 11-12 (Steam Power Machinery) *or* M.E. 13-14 (Steam Power Machinery) Mech. 102 (Analytical Mechanics)
19-20—Engine Design	M.E. 39-40 (Machine Design) M.E. 11-12 (Steam Power Machinery) M.E. 17-18 (Eng. Thermodynamics)
22—Gas Power	M.E. 19 (Engine Design) M.E. 33 (Standard Tests and Research Methods
25—Steam Power	M.E. 96S (Steam Power Plant Summer Work)
31-32—Standard Tests and Research Methods *Parallel* M.E. 17-18 (Engineering Thermodynamics)	M.E. 11-12 (Steam Power Machinery)
33—Standard Tests and Research Methods (Continuation of M.E. 31-32)	M.E. 17-18 (Eng. Thermodynamics) M.E. 31-32 Std. Tests and Research Methods M.E. 96S (Steam Power Plant Summer Work)
35-36—Kinematics of Machinery	Math. 3-4 (Analytical Geometry)
37—Machine Design	Drafting 7
39-40—Machine Design *Parallel* C.E. 53	M. E. 35-36 (Kinematics of Machinery)
41—Machine Design (Short course of M.E. 39-40) *Parallel* C.E. 53 for E.E. C. E. 53 for C. E.	
(For M.E.)	M.E. 35-36 (Kinematics of Machinery) M.E. 60 Hydraulic Laboratory C.E. 78 (Hydraulics)
(For C.E.)	M.E. 63 Hydraulic Laboratory C.E. 75 (Hydraulics)
52—Organization and Management *Parallel* M.E. 68	M.E. 78 (Kinematics of Machinery)
53—Steam Turbines. (For M.E.)	M.E. 17-18 (Eng. Thermodynamics) M.E. 31-32 (Standard Tests, etc.)
(For E.E.)	M.E. 17-18 (Eng. Thermodynamics) M.E. 76 (Standard Tests, etc.)
54—Shop Processes	M.E. 94S (Shop and Factory: Summer Work) M.E. 39 (Machine Design)
56—Water Power Installations *Parallel* M.E. 60 (Hydraulic Laboratory)	C.E. 77 (Hydraulics)
59—Empiric Design	Draft. 1 or 2 (Elements of Mechanical Drafting)
60—Hydraulic Laboratory. (For E.E.) *Parallel* (For M.E.) C.E. 78. (Hydraulics)	C.E. 77 (Hydraulics)
63—Hydraulic Laboratory *Parallel* C.E. 75 (Hydraulics)	
64—Air Machinery	M.E. 17 (Eng. Thermodynamics)
66—Elevators and Conveyors	M.E. 39 (Machine Design)
68—Shops and Factories *Parallel* M.E. 52 (Organization and Management)	E.E. 103 (Electric Power)
70—Pumping Machinery *Parallel* C.E. 78 (Hydraulics)	M.E. 17 (Eng. Thermodynamics)

Subject	Pre-requisite
Mechanical Engineering (*Continued*):	
72—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
74—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
76—Standard Tests. (For E.M., Chem.E. and Met.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Eng. Thermodynamics)
77—Standard Tests. (For C.E., Chem.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Eng. Thermodynamics)
78—Kinematics	M.E. 17-18 (Eng. Thermodynamics) (For C.E.)
80—Experimental Mechanical Laboratory *Parallel course* M.E. 14	Math. 3-4 (Analytical Geometry)
94S—Shop and Factory Summer Work	Sh.Wk. 1 (Wood Turning and Pattern Making) Sh.Wk. 2 (Molding and Foundry Practice) Sh.Wk. 12 (Forging)
82—Heating and Ventilation	M.E. 17-18 (Eng. Thermodynamics)
96S—Steam Power Plant Summer Work	M. E. 31-32 (Standard Tests, etc.)
97—Mechanical Apparatus for Chemical Factories	M.E. 17-18 (Eng. Thermodynamics) M.E. 11 and 12 M.E. 17 and 18
Metallurgy	
101—General Metallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
111—Metallurgy of Copper	Met. 101 (General Metallurgy)
118—Metallurgy of Copper. (Advanced Course)	Met. 111 (Metallurgy of Copper)
122—Metallurgy of Lead, Silver, Gold and Zinc	Met. 111 (Metallurgy of Copper)
128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. (Advanced Course)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
131—Metallurgy of Iron and Steel Prerequisite or *Parallel* Met. 101 (General Metallurgy)	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
134—Metallurgy of Iron and Steel	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
138—Metallurgy of Iron and Steel. (Advanced Course)	Met. 131 (Metallurgy of Iron and Steel)
141—Electrometallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
148—Electrometallurgy. (Advanced Course)	Met. 141 (Electrometallurgy)
151—Constitution and Properties of Alloys *Parallel* Met. 131 (Met. of Iron and Steel)	Met. 111
155-6—Metallography of Iron, Steel and Industrial Alloys	Met. 131 (Met. of Iron and Steel) *or* Met. 134 (Metallurgy of Iron and Steel)
158—Constitution and Properties of Alloys. (Advanced Course)	Met. 151 (Constitution and Properties of Alloys)
72—Metallurgical Laboratory *Parallel* Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)	Met. 111 (Metallurgy of Copper)
171—Metallurgical Laboratory *Parallel* Met. 101 (General Metallurgy) and Met. 111 (Metallurgy of Copper)	Met. 171
172—Metallurgical Laboratory	Met. 171
173-174—Metallurgical Laboratory	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)

Subject	Pre-requisite
Metallurgy (*Continued*):	
175—Metallurgical Investigation *Parallel* Met. 131 (Metallurgy of Iron and Steel, and Met. 141 (Electrometallurgy)	
77—Met. Plant Construction	Draft. 3-4, 7-8 C.E. 53; Met. 122, 64S and 66S
62S—Summer Course in Non-Ferrous Metallurgy	Met. 101 (General Metallurgy)
64S—Summer Course in Ferrous Metallurgy	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
66S—Summer Course in Non-ferrous Metallurgy	
82S—Summer School in Assaying	Chem. 3-4 and 61-62
81—Assaying	Mineralogy 1-2, or 7-8 Chem. 3-4 and 61-62
182—Assaying	Mineralogy 1-2, or 7-8
186—Assaying	Met. 81 or 182
Mineralogy	
1-2—Descriptive and Determinative Mineralogy	Entrance Chemistry Entrance Physics
5—The Minerals of Building Stones	Entrance Chemistry Entrance Physics
6—Optical Mineralogy	Min. 5 (Minerals of Building Stones) *or part of* Min. 1-2 (Descriptive and Determinative Mineralogy) *or equivalent*
7-8—Descriptive and Determinative Mineralogy. (Modification of Min. 1)	Entrance Chemistry Entrance Physics
9—Mineralogy and Crystallography	Min. 15-16
15-16—Determinative Mineralogy	Entrance Chemistry Entrance Physics
Mining	
51—Excavation and Tunneling.	Entrance Mathematics Entrance Chemistry Entrance Physics
52—Boring and Shaft Sinking	E.M. 51 (Excavation and Tunneling)
53—Excavation, Tunneling, Boring and Shaft Sinking.) (For C.E.) (Condensation of E.M. 51 and 52)	Entrance Mathematics Entrance Chemistry Entrance Physics
54—Exploration, Development, and Methods of Working. (For E.M. and Met.E.)	Geol. 5-6
Prerequisite or *Parallel*	Geol. 105-106 (Economic Geology) E.M. 51 and 52 (Excavation and Tunneling)
56—Mine Engineering	E.M. 54
Prerequisite or *Parallel*	E.M. 71-72 (Mine Plant) C.E. 76 (Hydraulics) C.E. 28 (Surveying)
71-72—Mine Plant	E.M. 51-52 E.M. 54 (Exploration, Development and Methods of Working) M.E. 13-14 (Steam Power Machinery)
73—Mine Constructions. (For E.M. and Met.E.)	
75—Design of Mine Plant *Parallel* E.M. 71-72 (Mine Plant)	Draft. 3-4, 7-8 (Structural Drafting) C.E. 53 (Elasticity and Resistance of Materials)
77-78—Graduating Thesis or Project	All required subjects in Mining
80—Mill Constructions	M.E. 13-14 (Steam Power Machinery)
81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. (For E.M. and Met.E.)	Min. 1-2 (Descriptive and Determinative Mineralogy) Phys. 3-4 (Elementary Mechanics and General Physics) Mech. 102 (Analytical Mechanics)

Subject	Pre-requisite
Mining (*Continued*):	
82—Ore-Dressing Laboratory. (For E.M. and Met.E.)	E.M. 81 (Ore Dressing, Milling, and the Mechanical Preparation of Coal)
91—Mine Administration. (For E.M. and Met.E.)	E.M. 54 (Exploration, Development and Methods of Working)
94—Mining Law. (For E.M. and Met.E.)	C.E. 27 (Surveying) E.M. 54 (Exploration, Development and Methods of Working)
95—Mining Conference. (Optional)	
58—Summer Class in Mine Surveying	C.E. 27 (Surveying)
59—Summer Course in Practical Mining	M.E. 13-14 (Steam Power Machinery) E.M. 54 (Exploration, Development and Methods of Working) E.M. 51 and 52 C.E. 15 and 27 Geol. 105-106
Physical Education	
A1-A2	
B1-B2	Phys. Ed. A1-A2
Physics and Mechanics	
Mech. 1—Mechanics: Statics.	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 3-4—General Physics: Mechanics, Wave-motion, Heat and Light	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 5—Electricity	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 43-44—Physical Laboratory *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 55—Physical Measurements *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Mech. 102—Mechanics	Mech. 1 (Mechanics: Statics) Phys. 3 (Mechanics, Wave-Motion, and first part of Heat) Math. 64 and 65 (Differential and Integral Calculus)
Mech. 105—Thermodynamics	Mech. 102 (Mechanics)
Mech. 107-108—Theory of Electricity and Magnetism	Mech. 102 (Mechanics)
Mech. 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits	Mech. 107-108 (Theory of Electricity and Magnetism)
Shop Work	
1—Wood-turning and Pattern Making. (For M.E.)	
2—Molding and Foundry Practice. (For M.E.)	
10S—Machine Work. (For M.E.)	Shop Work 103 (Machine Work)
11—Machine Work. (For M.E.)	
12—Forging. (For M.E.)	
13-14—Machine Work. (For E.E.)	
15—Forging and Foundry Practice. (For C.E.)	
16—Machine Work. (For C.E.)	
18S—Pattern-making. (For Chem.E.)	
Zoology	
7—Sanitary Biology	Bacteriology 101 (Sanitary Bacteriology)

GENERAL INFORMATION REGARDING COLUMBIA UNIVERSITY

Students in the Schools of Mines, Engineering and Chemistry may enjoy every advantage to be derived from the resources of the University. The University occupies thirty-six buildings, and its grounds cover thirty-five acres. The number of officers of instruction in 1911-12 was 761, and of resident students 7,429.

University Library The Library contains about 473,000 bound volumes, catalogued both by authors and by subjects.

It is open each week-day from 8.30 A.M. until 11 P.M. (in summer, 10 P.M.). All students and graduates have free access and may draw books for home use.

Physical Exercise The Gymnasium is open each week-day from 9.00 A.M. to 7 P.M.; and on Mondays, Thursdays, and Saturdays until 10 P.M.

Every student is entitled to a physical examination by the Medical Director and to advice as to the kind and amount of exercise best adapted to his needs. For the Gymnasium fee see page 18.

The main exercising room is 35 feet high, semicircular in shape, and has an area of 16,000 square feet. It is well lighted and well ventilated. Above are the 10-lap running track, rooms for fencing, boxing, and handball, dressing-rooms with 1,804 steel lockers, and 32 shower-baths. Below the exercising room is the semicircular swimming pool, 100 feet by 50, and 4 to 10 feet deep, and shower-, needle-, and tub-baths.

A two-hour course in Physical Education is prescribed for all first and second year undergraduate students, arranged with a view to securing: first, health; second, strength, control, efficiency, and endurance; third, erect carriage.

There are on South Field a practice field for baseball, lacrosse, and football, a quarter mile running track, tennis courts, and the University Boat House is within easy reach.

Employment Committee The Employment Committee endeavors to give students who need it the opportunity to earn enough for partial or complete support, and to extend assistance in other ways. The office of the secretary of the Committee is in Room 312, East Hall. Communications should be addressed to the Committee. Some of the openings available are: private tutoring, translating, addressing, copying of various sorts, teaching in evening schools, stenography. During the year 1910-11 the student earnings reported to the Committee amounted to $75,709.45.

THE GREEN AND UNION THEOLOGICAL SEMINARY FROM QUADRANGLE

Preference is naturally given, in case of a choice of applicants, to those who, as strangers in New York, are not likely to hear of positions through other channels. No prospective student should come to Columbia expecting to depend entirely or even largely upon the assistance of the Committee, and every student should be prepared to meet at least the expenses of the first half-year—say $250.

The chiefs of clinic in the Medical School give advice without charge to students on the lists of the Committee.

There are also Appointment Committees whose duty it is to recommend graduates for teaching or other positions in colleges and universities and to assist competent men to obtain such positions.

Medical Visitor

A University Medical Visitor renders medical assistance to students without family physicians in New York for a remuneration to be arranged between himself and individual patients. The medical visitor is Dr. D. S. D. Jessup, office hours 5 to 6 daily, at 542 West 112th Street (telephone, 6382 Morningside).

Residence Halls

There are two University dormitories on South Field, with accommodations for 500 men; Hartley Hall, a memorial to the late Marcellus Hartley, and Livingston Hall, named in memory of Robert R. Livingston, of the class of 1765. Each building is 137 feet by 60 and 10 stories high. They have electric light, steam heat, telephones, elevator and shower baths.

The two Halls contain 600 outside rooms, both single and double, which may be rented singly or in suites. The bedrooms average 8 feet by 14.6, and the studies 10 by 14.6. All are 9 feet high. Each bedroom has a clothes-closet and an enamelled basin with hot and cold water, and is provided with heavy oak furniture.

The entrance to each building faces the campus, and leads directly into an assembly room 60 feet square. This room runs up through two stories and has a large open fireplace opposite the entrance.

The weekly charge for a single room ranges from $2.60 to $4.75 for the academic year of thirty-nine weeks. A pamphlet with floor plans and rental charges and containing the Hall Regulations may be had upon application to the Secretary of the University. Rooms will be assigned in the order of receipt of applications, which should be made on a blank provided by the Superintendent of Buildings and Grounds.

University Commons

The University Commons (under student management) for the accommodation of the men living in the Residence Halls is conducted upon a system combining *table d'hôte* and *à la carte*. The Commons, which has accommodations for 450 men, is in University Hall, and is open daily from 7.30 A.M. to 7 P.M. There is also a large buffet lunch room.

Other Accommodations Besides the dormitories and the Greek Letter Society club-houses there are many good boarding-houses and apartments near the University, a card-catalogue of which is kept at Earl Hall.

Public Lectures, etc. In addition to the regular courses of instruction, numerous public lectures are given at the University, ordinarily by persons of distinction who are not members of the teaching staff. The University maintains close relations with the other educational and public institutions of the city, and students enjoy unusual privileges at them. Students are also frequently given the opportunity to enjoy important dramatic and musical performances at a considerably reduced cost.

St. Paul's Chapel St. Paul's Chapel, the gift of Olivia Egleston Phelps Stokes and Caroline Phelps Stokes, as a memorial to their parents, is a beautiful cruciform building with 1,050 sittings. Service, at which attendance is voluntary, is held every week-day except Wednesday and Saturday, at noon, the period from 12 to 12.20 being set apart by the University for religious exercises; on Wednesday afternoons at 5.10; and on Sunday afternoons at 4 P.M. There are also frequent organ recitals.

Earl Hall Earl Hall, the home of the religious, philanthropic, and social organizations and interests, is open to all students, without expense, from 8.30 A.M. to 10 P.M. daily, under the management of its Secretary, who is also Secretary of the University Young Men's Christian Association. Provision for the meetings of student organizations is made in the following order: Societies the purpose of which is (1) primarily religious; (2) primarily philanthropic; (3) primarily literary; and (4) miscellaneous student organizations. The building is also much used as a general student club house.

Student Organizations The various student organizations, while self-governing, are subject to the following regulations: The schedules of public contests and performances must be approved by the University Committee on Student Organizations; budgets for expenditure are approved and checked by the Comptroller of Student Organizations; the University Committee on Athletics, consisting of three graduates, two students and two University officers, adopt and administer rules of eligibility not involving questions of scholarship and govern participation in inter-collegiate athletics. A pamphlet containing the full regulations, the constitution of the Athletic Association and the constitution of the Board of Student Representatives may be obtained from the Secretary of the University.

The Degree of A.M.

A college graduate who completes with marked distinction one of the regular professional courses may be recommended for the degree of Master of Arts if, while pursuing his professional course, he shall have taken additional work, under the Faculty of Pure Science, Philosophy or Political Science, to the extent of a major subject, and have presented a satisfactory essay upon an assigned topic. A detailed statement of the requirements for this degree and also for the Ph.D., with a list of subjects which may be offered, will be found in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science.* See also page 21.

Fellowships

For information as to the fourteen University Fellowships, of the annual value of $650 each, and the several endowed fellowships open to qualified candidates for the degree of Master of Arts and Doctor of Philosophy, see the *Announcement of the Faculties of Political Science, Philosophy and Pure Science,* or the University Catalogue.

The three following are of particular interest to students of Mines, Engineering and Chemistry, who are advised to familiarize themselves with the special regulations governing them:

The Tyndall Fellowship for the Encouragement of Research in Physics, endowed by Professor John Tyndall, and of an annual value of $648; the Barnard Fellowship for Encouraging Scientific Research, endowed by the bequest of the late President Barnard, annual value $500; and the Ernest Kempton Adams Research Fellowship, founded by Mr. Edward Dean Adams in memory of his son, Ernest Kempton Adams, annual value $1,250.

Students

In 1911-12 the registration in the Schools of Mines, Engineering and Chemistry is as follows:

First-year class	184
Second-year class	154
Third-year class	186
Fourth-year class	134
Non-matriculated	13
Students from Columbia College	13
Total	684

Of students registered, 87 already held a college or technical degree, representing 28 institutions. In addition there are registered under the Faculty of Pure Science as candidates for the A.M. and Ph.D. degrees 17 students with some branch of Engineering (including 9 in Highway Engineering) and 56 with Chemistry as a major subject.

ALUMNI ORGANIZATION

The Alumni Association of the Schools of Science of Columbia University includes in its membership graduates of the Schools of Mines, Engineering and Chemistry. Associate membership is open to non-graduates, members of classes that have graduated.

Honorary membership is open to all persons eminent in Science who are or have been connected with any of the Schools of Science of Columbia University.

Its officers for 1912-13 are:

President, Francis M. Simonds, E.M., '87.
Vice-President, Wheaton B. Kunhardt, E.M., '80.
Treasurer, John S. Douglas, E.E., '90.
Secretary, Ralph E. Mayer, C.E., '79.
Post Office Substation 84, New York City.

Board of Managers

T. H. Leggett, E.M., '79.
Gano Dunn, E.E., '93.
E. C. Church, C.E., '04.
R. M. Olyphant, M.E., '06.
T. R. Brinley, C.E., '84.
W. I. Slichter, E.E., '96.
W. Newell, M.E., '07.
E. C. Kendall, Chem., '08.
G. H. Clark, C.E., '93.

Delegates to the Alumni Council

Charles B. Going, Ph.B., '82
George H. Clark, C.E., '93.
Daniel E. Moran, C.E., '84.

A complete list of the Alumni, giving the addresses of each, and in the case of those who are members of the Association, a detailed record of their professional careers, is published and may be had on application to the Alumni Secretary, Columbia University.

The Alumni Secretary will also be glad to put prospective students in communication with Alumni in different parts of the country. Such Alumni are often able in a personal interview to furnish information regarding the Schools of Mines, Engineering and Chemistry which inquirers at a distance could obtain in no other way.

General Alumni Organizations

Alumni Council:

John Howard Van Amringe, '60, Chairman
George Brokaw Compton, '09, Secretary, Columbia University

Society of the Early Eighties:

Reginald H. Sayre, '81, President
Girard Romaine, '82, Secretary, 68 Broad Street, New York City

Society of Older Graduates:

Pierre de P. Rickets, 71 S, '76 Ph.D., President

William de L. Benedict, '74 S, Secretary, 43 Cedar Street, New York City.

Society of the Upper Eighties:

Charles H. Mapes, '85, President

Edward L. Dodge, '88 S. Secretary, 32 Nassau Street, New York Ctiy

Local Association Secretaries

Albany—Rev. Roelif H. Brooks, '00 (President), 80 Lancaster Street, Albany, N. Y.

California—Dr. John C. Spencer, '82, '85 M., Butler Building, San Francisco, Cal.

China—Dr. F. E. Hinckley, '05 Ph.D., clerk, United States Court for China, Shanghai, China.

Colorado—Roger W. Toll, '06, 790 Washington Street, Denver, Colo.

Columbia (Missouri)—E. W. Hinton, '91 L., Columbia, Mo.

Connecticut—John D. Irving, '96, Yale University, New Haven Conn.

Cuba—Humberto Fonts, '09, S, Empedrado 59, Havana, Cuba.

District of Columbia—George Oakley Totten, Jr., '91 F. A., 808 Seventeenth Street, N. W., Washington, D. C.

Illinois—Dr. Emory Hill, '04, 22 East Washington Street, Chicago, Ill.

Indiana—Professor George H. Danton, '02, Butler College, Indianapolis, Indiana.

Japan—Rev. Kentok Hori, '07 A. M., College of Literature, Imperial University of Tokio, Tokio, Japan.

Kansas City—Dr. Walter S. Sutton, '07 M, 810-815 Rialto Building, Kansas City, Mo.

Kentucky—F. A. Busse, '03 S., 800 Third Street, Louisville, Ky.

Louisiana—Ralph J. Schwarz, '05 L (President), 805 Common Street, New Orleans, La.

Madison (Wisconsin)—John L. Kind, '06, Ph.D. (President), University of Wisconsin, Madison, Wis.

Mexico—Herbert C. Enos, '06 S, P. O. Box 1583, Gante No. 1, Mexico City, Mexico.

Michigan—Dr. Theodore A. McGraw, Jr., '02 M., 73 Cass Street, Detroit, Michigan.

Minnesota—Professor Gregory D. Walcott, '99 A.M., '04 Ph.D., Hamline University, St. Paul, Minn.

Nashville—Eugene Tavenner, '01, Murfreesboro, Tenn.

Nebraska—Dr. C. W. Pollard, '99 M., Paxton Block, Omaha, Neb.

New England—Franklin S. Hoyt, '05 A.M., care Houghton Mifflin and Company, 4 Park Street, Boston, Mass.

New Jersey—W. G. Brandley, '08, Caldwell, New Jersey.

North Carolina—Henry J. Highsmith, T.C., Wake Forest College, Wake Forest, N. C.

Northeastern Pennsylvania—Clarence D. Shrady, '95 S., Allentown, Pa.

Ohio, Northern (Cleveland)—Frederic W. Striebinger, '95 F.A., 1215 New England Building, Cleveland, Ohio.

Ohio, Central (Columbus)—Professor F. P. Graves, '90, Ohio State University, Columbus, Ohio.

Paris—Charles F. Beach, Jr., '81 L., 95 rue des Petits-Champs, Paris, France.

Philadelphia—Stanley Kidder Wilson, '02, Swarthmore, Pennsylvania.

Pittsburg—W. J. Strassburger, '01 F.A., Glassmere, Pa.

St. Louis—William E. Baird, '02 L. Law Department, City Hall, St. Louis, Mo.

Utah—C. H. Doolittle, '85 S, 1242 East South Temple, Salt Lake City, Utah.

Virginia—Jackson Davis, '08 A.M., Board of Examiners, Petersburg, Va.

Washington—H. K. Benson, '07 Ph.D., University of Washington, Seattle, Washington.

Western New York—W. W. Cohn, '08, 1208 West Avenue, Buffalo, N. Y.

Wisconsin—H. W. Buemming, '95 F.A., 521 Jackson Street, Milwaukee, Wisconsin.

Yonkers—James F. Prince, '08, 149 N. Broadway, Yonkers, N. Y.

Academic Calendar

1912-1913

1912—July 8, Monday. Thirteenth Summer Session opens.

August 16, Friday. Thirteenth Summer Session closes.

September 16, Monday. Entrance examinations and examinations for deficient and debarred students begin.

September 18, Wednesday. Registration begins.

September 24, Tuesday. Registration ceases for students previously matriculated. Later applications received only on payment of an additional fee of $5.

September 25, Wednesday. First half-year, 159th year, begins. Registration ceases for students not previously matriculated. Later applications received only on payment of an additional fee of $5. Scholars to report to the Registrar.

September 26, Thursday. Lectures and recitations begin in courses.

October 15, Tuesday. Stated meeting of University Council.

November 5, Tuesday. Election day, holiday.

November 27, Wednesday. University service in St. Paul's Chapel.

November 28, Thursday, to November 30, Saturday, inclusive. Thanksgiving holidays.

December 15, Sunday. Memorial service, St. Paul's Chapel.

December 17, Tuesday. Stated meeting of University Council.

December 23, Monday, to

1913—January 4, Saturday, inclusive. Christmas holidays.

January 6, Monday. Last day for filing applications for entrance examinations.

January 13, Monday. Mid-year entrance examinations begin.

January 22, Wednesday. Mid-year examinations begin.

February 4, Tuesday. First half-year ends.

February 5, Wednesday. Second half-year begins. University service in St. Paul's chapel. Registration ceases for students entering second half-year. Later applications received only on payment of an additional fee of $5. Scholars to report to the Registrar.

February 12, Wednesday. Alumni Day.

February 18, Tuesday. Stated meeting of University Council.

February 22, Saturday. Washington's Birthday, holiday.

March 20, Thursday, to March 24, Monday, inclusive. Easter holidays.

April 15, Tuesday. Stated meeting of University Council.

May 1, Thursday. Last day for filing applications for scholarships.

May 14, Wednesday. Final examinations begin.

May 30, Friday. Memorial Day, holiday.

June 1, Sunday. Baccalaureate service.

June 2, Monday. Class Day.
June 4, Wednesday. Commencement Day.
June 11, Wednesday. Second half-year ends.
June 16, Monday. Entrance examinations begin.

July 7, Monday. Fourteenth Summer Session opens.

August 15, Friday. Fourteenth Summer Session closes.

September 15, Monday. Entrance examinations and examinations for deficient and debarred students begin.

September 17, Wednesday. Registration begins.

September 23, Tuesday. Registration ceases for students previously matriculated. Later applications received only on payment of an additional fee of $5.

September 24, Wednesday. First half-year, 160th year, begins. Registration ceases for students not previously matriculated. Later applications received only on payment of an additional fee of $5. Scholars to report to the Registrar.

The last day of the second half-year falls on the second Wednesday in June, and the academic year opens 37 weeks before that date. The second half-year opens on Wednesday, 19 weeks from the opening of the first half-year.

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Thirteenth Series No. 19 May 24, 1913

Columbia University Bulletin of Information

SCHOOLS OF MINES, ENGINEERING AND CHEMISTRY

MINING
METALLURGY
CIVIL ENGINEERING
SANITARY ENGINEERING
ELECTRICAL ENGINEERING
MECHANICAL ENGINEERING
CHEMICAL ENGINEERING
CHEMISTRY

ANNOUNCEMENT

1913-1914

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New York, N. Y.

Columbia University
Bulletin of Information

(Issued 25 times during the Academic year, monthly in November and December, and weekly between February and June. Entered as second-class matter at the New York, N. Y., Post Office, Dec. 22, 1900, under Act of July 16, 1894.)

These bulletins include:

1. The Report of the President and Treasurer to the Trustees.
2. The Catalogue of the University, issued in December, price 25 cents.
3. The Announcements of the several Colleges, Schools, and Divisions, issued in the Spring, and relating to the work of the next year. These are made as accurate as possible, but the right is reserved to make changes in detail as circumstances require. The current number of any of these Announcements will be sent without charge upon application to the Secretary of the University.

B.-9,000-1913

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FACULTY OF APPLIED SCIENCE

Officers of the Faculty

FREDERICK ARTHUR GOETZE, M.Sc....*Dean and Member of the University Council, ex-officio*

HENRY S. MUNROE, E.M., PH.D., SC.D.....*Elected Delegate to the University Council*

ALEXANDER SMITH, PH.D...*Elected Delegate to the University Council*

ADAM LEROY JONES, PH.D.....*Secretary*

Committee on Instruction

DEAN GOETZE *(Chairman)*, Professors KEMP, LOVELL, MAYER, MUNROE, WALKER, WENDELL and WHITAKER

Committee on Admissions

Professors JONES (*Chairman*), MAYER, SLICHTER and THOMAS

The Faculty

NICHOLAS MURRAY BUTLER.....*President of the University*

A.B., Columbia, 1882; A.M., 1883; Ph.D., 1884; LL.D., Syracuse, 1898; Tulane, 1901; Johns Hopkins, Princeton, Yale, and University of Pennsylvania, 1902; Chicago, 1903; Manchester and St. Andrew's, 1905; Cambridge, 1907; Williams, 1908; Harvard and Dartmouth, 1909; D.Litt., Oxford, 1905; Jur.D. Breslau, 1911; Officer de la Légion d'Honneur, 1906, Commander, 1912; Order of the Red Eagle (Prussia), Commander, 1910; Member American Academy of Arts and Letters, 1911.

FREDERICK ARTHUR GOETZE.....*Dean of the Faculty*

M.Sc., Columbia, 1905.

HENRY S. MUNROE.....*Professor of Mining*

E.M., Columbia, 1869; Ph.D., 1876; Sc.D., 1904.

ALFRED J. MOSES.....*Professor of Mineralogy*

E.M., Columbia, 1882; Ph.D., 1890.

JAMES FURMAN KEMP.....*Professor of Geology*

A.B., Amherst, 1881; Sc.D., 1906; E.M., Columbia, 1884; Member National Academy of Science.

ROBERT PEELE.....*Professor of Mining*

E.M., Columbia, 1883.

WILLIAM HALLOCK.....*Professor of Physics*

A.B., Columbia, 1879; Ph.D., Würzburg, 1881; Phar.D., National College of Pharmacy, 1892.

[1]FRANCIS B. CROCKER.....*Professor of Electrical Engineering*

E.M., Columbia, 1882; Ph.D., 1895.

MICHAEL IDVORSKY PUPIN.....*Professor of Electro-Mechanics*

A.B., Columbia, 1883; Sc.D., 1904; Ph.D., Berlin, 1889; Member National Academy of Science.

WILLIAM H. BURR.....*Professor of Civil Engineering*

C.E., Rensselaer Polytechnic, 1872.

THOMAS SCOTT FISKE.....*Professor of Mathematics*

A.B., Columbia, 1885; A.M., 1886; Ph.D., 1888.

[1]Absent on leave, 1913-14.

HAROLD JACOBY.....*Rutherfurd Professor of Astronomy*
A.B., Columbia, 1885; Ph.D., 1895.

EARL B. LOVELL.....*Professor of Civil Engineering*
C.E., Cornell, 1891.

JAMES MACAY.....*Professor of Mathematics*
C.E., Columbia, 1888; Ph.D., 1899.

MARSTON TAYLOR BOGERT.....*Professor of Organic Chemistry*
A.B., Columbia, 1890; Ph.B., 1894; LL.D., Clark, 1909.

J. LIVINGSTON RUTGERS MORGAN.....*Professor of Physical Chemistry*
B.S., Rutgers, 1892; A.M. and Ph.D., Leipzig, 1895.

AMADEUS W. GRABAU.....*Professor of Palæontology*
S.B., Massachusetts Institute of Technology, 1896; S.M., Harvard, 1898; S.D., 1900.

RALPH EDWARD MAYER..*Associate Professor of Engineering Draughting*
C.E., Columbia, 1879.

CASSIUS JACKSON KEYSER.....*Adrain Professor of Mathematics*
B.S., Missouri, 1892; A.M., Columbia, 1896; Ph.D., 1901.

GEORGE L. MEYLAN....*Associate Professor of Physical Education and Medical Director of the Gymnasium*
M.D., New York University, 1896; B.S., Harvard, 1902; A.M., Columbia, 1904.

LEA MCILVAINE LUQUER.....*Assistant Professor of Mineralogy*
C.E., Columbia, 1887; Ph.D., 1894.

HENRY CLAPP SHERMAN.....*Professor of Food Chemistry*
B.S., Maryland Agricultural College, 1893; A.M., Columbia, 1896; Ph.D., 1897.

ALBERT P. WILLS.....*Professor of Mathematical Physics*
B.E.E., Tufts, 1894; Sc.D., 1911; Ph.D., Clark, 1897.

SAMUEL A. TUCKER.....*Assistant Professor of Electro-Chemistry*
Ph.B., Columbia, 1895.

CHARLES EDWARD LUCKE.....*Professor of Mechanical Engineering*
B.S., College of the City of New York, 1895; M.S., New York University, 1899; Ph.D., Columbia, 1902.

[1]WALTER RAUTENSTRAUCH.....*Professor of Mechanical Engineering*
B.S., Missouri, 1902; M.S., Maine, 1903.

[2]WILLIAM CAMPBELL.....*Associate Professor of Metallurgy*
B.Sc., Durham University, 1898; D.Sc., 1905; M.Sc., Royal School of Mines, 1903; Ph.D., Columbia, 1903; A.M., 1905.

EDWARD LAWRENCE KURTZ.....*Assistant Professor of Mining*
E.M., Columbia, 1893.

CARLTON CLARENCE CURTIS.....*Associate Professor of Botany*
A.B., Syracuse, 1889; Ph.D., 1893; A.M., Columbia, 1892.

S. ALFRED MITCHELL.....*Assistant Professor of Astronomy*
A.M., Queens, 1894; Ph.D., Johns Hopkins, 1898.

ARTHUR L. WALKER.....*Professor of Metallurgy*
E.M., Columbia, 1883.

GEORGE BRAXTON PEGRAM.....*Associate Professor of Physics*
A.B., Trinity College (N. C.), 1895; Ph.D., Columbia, 1903.

[1]Absent on leave, first half-year.
[2]Absent on leave, second half-year.

BERGEN DAVIS.....*Assistant Professor of Physics*
B.S., Rutgers, 1896; A.M., Columbia, 1900; Ph.D., 1901.

ADAM LEROY JONES.....*Chairman of Committee on Undergraduate Admissions and Secretary of the Faculty*
A.B., Williams, 1895; Ph.D., Columbia, 1898.

CHARLES H. BURNSIDE.....*Assistant Professor of Mechanics*
B.S., Columbia, 1898; A.M., 1899.

MORTON ARENDT.....*Assistant Professor of Electrical Engineering*
E.E., Columbia, 1898.

CHARLES P. BERKEY.....*Assistant Professor of Geology*
B.S., Minnesota, 1892; M.S., 1893; Ph.D., 1897.

JOHN HAROLD MORECROFT..*Assistant Professor of Electrical Engineering*
E.E., Syracuse, 1904; B.S., 1907.

W. BENJAMIN FITE.....*Professor of Mathematics*
Ph.B., Cornell, 1892; Ph.D., 1901.

HERBERT E. HAWKES.....*Professor of Mathematics*
A.B., Yale, 1896; Ph.D., 1900.

WALTER IRVINE SLICHTER.....*Professor of Electrical Engineering*
E.E., Columbia, 1896.

GEORGE V. WENDELL.....*Professor of Physics*
B.S., Massachusetts Institute of Technology, 1892; Ph.D., Leipzig, 1898.

MILTON C. WHITAKER.....*Professor of Engineering Chemistry*
B.S., Colorado, 1897; M.S., 1899.

EVERETT J. HALL.....*Assistant Professor of Assaying*

FLOYD J. METZGER.....*Assistant Professor of Analytical Chemistry*
Ph.B., Buchtel, 1899; Ph.D., Columbia, 1902.

HARRY L. PARR.....*Assistant Professor of Mechanical Engineering*
A.B., Columbia, 1902; Mech.E., 1904.

SAMUEL OSGOOD MILLER.....*Assistant Professor of Drawing*
C.E., Columbia, 1895.

EDWARD F. KERN.....*Assistant Professor of Metallurgy*
B.S., Tennessee, 1897; Ph.D., Columbia, 1901.

HAL T. BEANS.....*Assistant Professor of Chemistry*
B.S., Nebraska, 1899; A.M., 1900; Ph.D., Columbia, 1904.

CHARLES W. THOMAS..*Assistant Professor of Mechanical Engineering*
Mech.E., Stevens Institute, 1884.

ARTHUR H. BLANCHARD.....*Professor of Highway Engineering*
C.E., Brown, 1890; A.M., Columbia, 1902.

THOMAS B. FREAS.....*Assistant Professor of Chemistry and Curator of the Chandler Museum*
A.B., Stanford, 1896; Ph.D., Chicago, 1911.

ALEXANDER SMITH.....*Professor of Chemistry*
B.S., Edinburgh, 1886; Ph.D., Munich, 1889.

THOMAS H. HARRINGTON.....*Assistant Professor of Drawing*
C.E., Columbia, 1889.

REGINALD J. S. PIGOTT.....*Assistant Professor of Steam Engineering*
Mech.E., Columbia, 1906.

FRANK C. SCHROEDER.....*Assistant Professor of Mechanics*
B.S., Wisconsin, 1907; C.E., 1910.

LEONARD D. NORSWORTHY.....*Assistant Professor of Civil Engineering*
C.E., Columbia, 1909; A.M., 1910.

DANIEL DANA JACKSON.....*Assistant Professor of Civil Engineering*
B.S., Massachusetts Institute of Technology, 1893; M.S., New York University, 1908.

Other Officers

HENRY ROGERS SEAGER.....*Professor of Political Economy*
Ph.B., Michigan, 1890; Ph.D., Pennsylvania, 1894.

Associates

FREDERICK A. HALSEY.....*Associate in Mechanical Engineering*
B.M.E., Cornell, 1878.

LINCOLN DE GROOT MOSS.....*Associate in Mechanical Engineering*

F. V. D. LONGACRE.....*Associate in Mechanical Engineering*

F. F. NICKEL.....*Associate in Mechanical Engineering*

Instructors

EDWARD K. JUDD.....*Instructor in Mining*
A.B., Williams, 1901; E.M., Columbia, 1904.

LEIGHTON B. MORSE.....*Instructor in Physics*
Ph.B., Iowa College, 1903; Ph.D., Columbia, 1908.

HAROLD W. WEBB.....*Instructor in Physics*
A.B., Columbia, 1905; Ph.D., 1909.

ARTHUR COLON NEISH.....*Instructor in Chemistry*
A.B., Queen's University, 1898; A.M., Columbia, 1900; Ph.D., 1904.

CHESTER A. DARLING.....*Instructor in Botany*
A.B., Albion, 1904; A.M., 1906; Ph.D., Columbia, 1909.

JOHN M. NELSON.....*Instructor in Organic Chemistry*
B.S., Nebraska, 1901; Ph.D., Columbia, 1907.

HERMON W. FARWELL.....*Instructor in Physics*
A.B., Dartmouth, 1902; A.M., 1906.

HARRY W. REDDICK..... *Instructor in Mathematics*
A.B., Indiana, 1904; A.M., Illinois, 1906; Ph.D., Columbia, 1911.

EDWARD D. THURSTON, JR.....*Instructor in Mechanical Engineering*
A.B., Columbia, 1905; Mech.E., 1907.

FREDERICK W. HEHRE.....*Instructor in Electrical Engineering*
E.E., Columbia, 1908.

JAMES S. MACGREGOR.....*Instructor in Civil Engineering*
B.S., Mass. Inst. of Technology, 1902; M.S., 1904.

JAMES KIP FINCH.....*Instructor in Civil Engineering*
C.E., Columbia, 1906.

ARTHUR LOWELL HERRICK.....*Instructor in Mechanical Engineering*
B.S., Dartmouth, 1909; C.E., Wisconsin, 1910.

NELS J. LENNES.....*Instructor in Mathematics*
S.B., Chicago, 1898; S.M., 1903; Ph.D., 1907.

MORRIS F. WEINRICH.....*Instructor in Physics*
Mech.E., Columbia, 1904; A.M., 1907.

WILLARD L. SEVERINGHAUS.....*Instructor in Physics*
A.B., German Wallace College, 1904; A.M., 1905.

FRANK L. MASON.....*Instructor in Electrical Engineering*
E.E., Columbia, 1909.

JESSE E. BEANS.....*Instructor in Drawing*

HENRY B. DROWNE.....*Instructor in Highway Engineering*
C.E., Brown, 1903.

GORDON H. GRAVES.....*Instructor in Mathematics*
B.S., Earlham, 1905; A.B., Haverford, 1906; A.M., Columbia, 1909.

ANDREW BENDER.....*Instructor in Analytical Chemistry*
A.B., Lebanon Valley College, 1906.

FREDERICK J. BARRY.....*Instructor in Chemistry*
Ph.D., Harvard, 1911.

[1]ARTHUR EDGAR.....Instructor in Chemistry
A.C., Lehigh, 1905; M.S., 1906; Ph.D., Mass. Inst. of Technology, 1912.

CHARLES A. FISCHER.....*Instructor in Mathematics*
A.B., Wheaton, 1905; A.M., Illinois, 1910; Ph.D., Chicago, 1912.

HARRY LINN FISHER.....*Instructor in Organic Chemistry*
A.B., Williams, 1909; A.M., Columbia, 1910.

HARRY F. GARDNER.....*Instructor in Mineralogy*
B.S., Michigan, 1912.

ROBERT M. ISHAM.....*Instructor in Analytical Chemistry*
B.A., Nebraska Wesleyan, 1909; M.A., University of Nebraska, 1910.

ROBERT H. LOMBARD.....*Instructor in Chemistry*
S.B., Massachusetts Institute of Technology, 1910.

ROBERT K. MURPHY.....*Instructor in Engineering Chemistry*
Chem.E., Columbia, 1911.

ARTHUR W. S. THOMAS.....*Instructor in Food Chemistry*
Chemist, Columbia, 1912.

HERBERT L. WHITTEMORE.....*Instructor in Mechanics*
B.S., Wisconsin, 1903.

GEORGE F. WIESER.....*Instructor in Mechanical Engineering*
Ph.B., Marietta, 1907; M.E., Cornell, 1910.

WILLIAM W. STIFLER.....*Instructor in Physics*
A.B., Shurtleff, 1902; A.M., Illinois, 1908; Ph.D., 1911.

WALTER W. MCKIRAHAN.....*Instructor in Analytical Chemistry*
A.B., Muskingum, 1905.

Lecturers

WILLIAM S. DAY.....*Lecturer in Physics*
A.B., Columbia, 1884; Ph.D., Johns Hopkins, 1897.

JULIAN BLANCHARD.....*Lecturer in Physics*
A.B., Trinity (N. C.), 1905; A.M., Columbia, 1909.

.....*Curator in Paleontology*

[1]Absent on leave 1913-14.

Assistants

BERNARD O. DODGE.....*Research Assistant in Botany*
Ph.B., Wisconsin, 1909.

HAROLD PERRINE.....*Assistant in Civil Engineering*
A.B., Columbia, 1908; A.M., 1909.

GEORGE A. SCOTT.....*Assistant in Physics*
B.S., Wisconsin, 1902.

EDGAR ALTENBURG.....*Assistant in Botany*
A.B., Columbia, 1911.

CLEMENT S. BRAININ.....*Assistant in Physics*
A.B., Columbia, 1908.

EVEREND L. BRUCE.....*Assistant in Mineralogy*
B.Sc., Queen's, 1909; B.A., 1911.

FRED D. FROMME.....*Assistant in Botany*
B.S., South Dakota State College, 1911.

GEORGE A. PFEIFFER.....*Assistant in Mathematics*
M.E., Stevens, 1910; A.M., Columbia, 1911.

WILLIAM HUNT MURPHY.....*Assistant in Physics*
B.S., McGill, 1908.

HAROLD P. BANKS.....*Assistant in Metallurgy*
A.B., Columbia, 1910; E.M., 1911.

ROBERT P. CALVERT.....*Research Assistant in Chemistry*
A.B., Oklahoma, 1909; A.M., 1910; S.M., Chicago, 1911.

JAMES B. COLEMAN.....*Assistant in Physics*
B.S., South Carolina, 1906; A.M., 1910.

OTTO KUNKEL.....*Assistant in Botany*
B.S., Missouri, 1909; A.M., 1910; A.M., 1911.

JOHN A. MCKINLEY, JR.....*Assistant in Drawing*

ALEXANDER LOWY.....*Laboratory Assistant in Electro-Chemistry*
B.S., Columbia, 1911; A.M., 1912.

FRANK J. MACKIN.....*Assistant in Mathematics*
B.S., Columbia, 1912.

PERCY W. PUNNETT.....*Assistant in Chemistry*
B.S., Rochester, 1911; A.M., Columbia, 1912.

WARREN S. SMITH.....*Assistant in Geology*
B.S., Washington, 1912.

FRANCIS M. VAN TUYL.....*Assistant in Paleontology*
A.B., Iowa, 1911; M.S., 1912.

.....*Assistant in Electrical Engineering*
.....*Assistant in Electrical Engineering*
.....*Assistant in Civil Engineering*
.....*Assistant in Physics*
.....*Laboratory Assistant in Chemistry*
.....*Laboratory Assistant in Chemistry*
.....*Laboratory Assistant in Physical Chemistry*
.....*Laboratory Assistant in Engineering Chemistry*

Special Lecturers for 1912-1913

ROBERT VAN ARSDALE NORRIS, E.M....*Drainage, Ventilation and the Mechanical Equipment of Mines*
Consulting Engineer, Coal Dept., D., L. & W. R. R. Co.

HARRY L. MEAD, E.M..*Principles involved in the examination, etc., of Hydraulic Gold Mines*
Consulting Engineer.

JAMES M. HYDE.....*Flotation Processes*
Formerly Professor of Mining at the University of Oregon.

JAMES R. FINLAY.....*The Elements of Mine Valuation*
Consulting Engineer.

BENJAMIN B. THAYER.....*The Butte Camp*
President, Anaconda Copper Mining Co.

ROSSITER W. RAYMOND, Ph.D.....*Engineering in Japan*
Consulting Engineer.

H. G. DAVIS.....*Anthracite Mining*
Superintendent, D., L. & W. Coal Co.

JAMES DOUGLAS, Ph.D.....*Metallurgy of Copper*
President, Copper Queen Consolidated Mining Co.

ARTHUR S. DWIGHT, E.M.....*The Sintering and Roasting of Ore*
President, Dwight-Lloyd Sintering Co.

GEORGE C. STONE, Chemist.....*Metallurgy of Zinc*
Consulting Engineer, New Jersey Zinc Co.

H. B. B. YERGASON, A.B.....*Metallurgy of Iron*
Advertising Manager, Rogers, Brown & Co.

W. F. THOMAS, C.E.....*Reinforced Concrete Construction*
Assistant Engineer, Weber Construction Co.

E. C. CHURCH, C.E.....*Specifications*
Department of Water Supply.

T. E. SNOOK, C.E.....*Architectural Engineering*
Chief Engineer, J. B. Snook & Sons.

LINCOLN DEGROOT MOSS.....*Elevators and Conveyors*
Consulting Engineer, Robins Conveyor Co.

FREDERICK A. HALSEY.....*Shop Processes*
Editor Emeritus, "American Machinist."

F. V. D. LONGACRE.....*Air Machinery*
Engineer, Ingersoll-Rand Co.

F. F. NICKEL.....*Pumping Machinery*
Engineer, Henry R. Worthington Co.

CLYDE R. PLACE, M.E..*Mechanical Features of the New Grand Central Terminal*
With Warren & Whetmore, Architects.

ROY V. WRIGHT, M.E.....*Steel Cars and their Construction*
Managing Editor, "Railway Age Gazette."

WILLIAM BRADSHAW, E.E.....*Electric Service Meters*
Westinghouse Electric and Mfg. Co.

W. W. LIGHTHIPE, E.E.....*Electric Elevators*
Otis Elevator Co.

WILLIAM H. CLINE.....*Application of Electric Motors*
General Electric Co.

E. A. LOF.....*Electricity in Mining*
General Electric Co.

C. J. FECHHEIMER.....*Present Tendencies in A. C. Design*
Crocker-Wheeler Co.

A. E. KENNELLY, A.M., D.Sc..*The Math. of Long Dist. Transmission of Power*
Professor Electrical Engineering, Harvard University.

C. G. KILBOURNE, E.E...*Distribution System of the New York Edison Company*
Assistant Chief Engineer, New York Edison Co.

R. B. TREAT, E.E.....*Application of Electric Motors to Steel Mills*
Chief of D. C. Design, Crocker-Wheeler Co.

FRED. B. COREY, M.E.....*Railway Signaling*
Union Switch and Signal Co.

S. H. BLAKE.....*Illumination*
General Electric Co.

A. L. POWELL, E.E.....*Illumination*
Assistant Chief Illuminating Engineer, General Electric Co., Harrison, N. J.

C. A. BROWNE, Ph.D.....*Sugar Production*
Chemist in charge of New York Sugar Trade Laboratory.

W. D. HORNE, Ph.D.....*Sugar Refining*
Chemist, National Sugar Refining Co.

H. C. HUMPHREYS, Ph.D.....*Starch and Glucose*
Chemist, Corn Products Refining Co.

C. E. NORTH, M.D.....*Sanitary Milk Production*
Consulting Sanitarian and Secretary, New York Dairy Demonstration Co.

ROBERT SCHWARZ, B.S.....*Fermentation Industries*
Fermentation Expert.

A. H. ELLIOTT, Ph.D.....*Gas Industry*
Consulting Engineer, Consolidated Gas Co.

CHARLES F. MCKENNA, Ph.D.....*Cement Industry*
Consulting Chemist.

A. A. NOYES, Ph.D.....*The Significance of the Free Energy of Chemical Reactions*
Director of Research Laboratory of Physical Chemistry, Mass. Inst. of Tech.

E. C. FRANKLIN, Ph.D.....*The Ammonia System of Acids, Bases and Salts*
Director of Hygienic Laboratory, Public Health Service, Washington.

MARCUS BENJAMIN, Ph.D., LL.D.....*Some Columbia Chemists*
Editor, U. S. National Museum.

F. K. CAMERON, Ph.D..*The Solution of the Potash Problem in America*
Bureau of Soils, U. S. Department of Agriculture.

H. L. FAIRCHILD, Sc.D.....*Glacial Geology of New York State*
Professor of Geology, Rochester University.

W. M. DAVIS, Sc.D....*Physiographic Methods and Descriptions with Illustrations from Special Regions*
America's leading Geographer and Physiographer.

EDWARD BRÜCKNER, Sc.D..*Climatic Oscillations and the Settlement of the Western United States*
Professor of Geography, University of Vienna, Austria.

CARL UHLIG, Ph.D.....*Geology of German West Africa*
Professor of Geography, University of Tubingen, Germany.

D. F. McDonald, Ph.D. ..... *Geology of the Panama Canal Zone*
Geologist, Panama Canal Zone.

Isaiah Bowman, Ph.D. ..... *Physiography of the Central Andes*
Assistant Professor of Geography, Yale University.

N. H. Darton.... *The Making of Structural Geologic Maps to Show Large Economic Relations*
U. S. Geological Survey.

John A. Bensel, M.E. ..... *Interrelationship of Highways, Waterways and Railways*
New York State Engineer, Albany, N. Y.

William H. Connell ..... *Organization of Municipal Highway Departments*
Chief, Bureau of Highways and Street Cleaning, Philadelphia, Pa.

Morris L. Cooke, M.E. . *Scientific Management as Applied to Highway Engineering*
Director, Department of Public Works, Philadelphia, Pa.

C. A. Crane.... *Proposals, Contracts and Bonds from the Standpoint of the Contractor*
Secretary, The General Contractors Association, New York City.

Walter W. Crosby, C.E., D.Sc. . *Engineering Duties and Responsibilities*
Chief Engineer to the Maryland Geological and Economic Survey and Consulting Engineer, Baltimore, Md.

Charles Henry Davis, C.E. ..... *National Highways*
President, National Highways Association, South Yarmouth, Mass.

A. W. Dow, Ph.B. ..... *Manufacture of Wood Paving Blocks*
Chemical and Consulting Paving Engineer, New York City.

Walter H. Fulweiler, B.Sc. . *Manufacture of Refined Water Gas Tar*
Engineer, Research Department, United Gas Improvement Company, Philadelphia, Pa.

John M. Goodell, B.Sc., in C.E. ..... *Essentials of Technical Writing*
Consulting Engineer, Engineering Record, New York City.

D. L. Hough, Ph.B.... *Highway Specifications from the Standpoint of the Contractor*
President, The United Engineering and Contracting Company, New York City.

Arthur N. Johnson, S.B. ..... *Concrete Highway Bridges*
State Highway Engineer, Springfield, Ill.

Nelson P. Lewis, A.B., C.E. . *Methods of Paying for the Construction of Street Pavements*
Chief Engineer, Board of Estimate and Apportionment, New York City.

J. C. Nagle, A.M., M.C.E. ..... *Highways of the Southwest*
Professor of Civil Engineering and Dean of the School of Engineering, Agricultural and Mechanical College of Texas, Houston, Texas.

Harold Parker ..... *Specifications Covering Patented Pavements*
First Vice-President, Hassam Paving Company, Worcester, Mass.

H. B. Pullar ..... *Mining of Gilsonite and Manufacture of Gilsonite Products*
Assistant Manager and Chief Chemist, American Asphaltum and Rubber Company, Chicago, Ill.

J. M. F. de Pulligny, A.B., B.S. *The Public Service of Roads in France*
Ingenieur en Chef des Ponts et Chaussees, et Directeur, Mission Francaise d'Ingenieurs aux Etats-Unis, New York City.

JOHN R. RABLIN.....*Metropolitan Park Systems*
Chief Engineer, Massachusetts Metropolitan Park Commission, Boston, Mass.

CLIFFORD RICHARDSON, A.B..*The Economics of Highway Construction*
Consulting Engineer, New York City.

PHILIP P. SHARPLES, A.B.....*Manufacture of Refined Water Gas Tar*
Chief Chemist, Barrett Manufacturing Company.

FRANCIS P. SMITH, Ph.B....*Maintenance of Sheet Asphalt Pavements*
Chemical and Consulting Paving Engineer, New York City.

ALBERT SOMMER, D.Ing.....*Mining and Refining of Asphaltic Oils*
Consulting Chemist, New York City.

GEORGE W. TILLSON, C.E.....*Details of Construction of Car Tracks in City Pavements*
Consulting Engineer, Borough of Brooklyn, New York City.

University Officers of Administration

FRANK DIEHL FACKENTHAL, A.B.....*Secretary of the University*
FRANK A. DICKEY, A.B.....*Registrar of the University*
CHARLES S. DANIELSON.....*Bursar*
HENRY L. NORRIS, M.E.....*Superintendent of Buildings and Grounds*
MALCOLM M. ROY, A.B.....*Secretary of Appointments*

Chaplain of the University

REV. RAYMOND C. KNOX, B.D.

Medical Director of the Gymnasium

GEORGE L. MEYLAN, M.D.

Secretary of Earl Hall

REUBEN A. MEYERS, A.B.

Health and Sanitary Officer

WILLIAM H. MCCASTLINE, M.D.

INTRODUCTORY

The first step for the foundation of a Faculty of Applied Science was taken in 1864, when the Trustees approved the creation of a School of Mines, in which courses were later established in civil engineering, chemistry, and metallurgy. The growth of these courses made it seem desirable to adopt some more comprehensive name than the historic title "School of Mines," so that in 1896 the Schools of Engineering and Chemistry were set off from the School of Mines, the three schools remaining, however, under the jurisdiction of a single faculty:

1. The School of Mines, with four-year courses leading to the degrees of Engineer of Mines and of Metallurgical Engineer.

2. The School of Engineering, with four-year courses in Civil Engineering, Sanitary Engineering, Electrical Engineering, and Mechanical Engineering, leading to the degrees of Civil Engineer, Electrical Engineer, and Mechanical Engineer respectively.

3. The School of Chemistry, with four-year courses, leading to the degrees of Chemist and Chemical Engineer.

The courses are intended to meet the requirements of the several professions indicated; and many of them permit a certain amount of specialization, particularly in the fourth year. The work in the School of Mines is so arranged that the student can emphasize the engineering, the metallurgical, or the geological side of his profession.

Candidates for a professional degree who have some special end in view are occasionally permitted to vary the regular course by substituting other courses offered under the Faculty of Applied Science. Students holding an approved academic degree may become candidates for the degree of Master of Arts or Doctor of Philosophy (see page 27). Non-matriculated students, properly qualified by age, special training and experience and by ability, may sometimes pursue advanced studies of original research.

In the regular Summer Session held at the University in July and August of each year and in the Department of Extension Teaching many courses of assistance to engineering students are offered. The *Announcement of the Summer Session* and the *Announcement of Extension Teaching* will be sent upon application to the Secretary of the University.

ADMISSION

Until 1914 admission to the Schools of Mines, Engineering and Chemistry will continue to be by examination, and by certificate from approved degree-granting institutions in so far as the certification corresponds specifically with the stated requirements. *Beginning with 1914 the new requirements described on page 19 will go into effect.*

Except for reasons of weight, candidates for admission to the first-year class must be at least eighteen years of age at the time of matriculation, and correspondingly older for admission to advanced standing. Each candidate must before admission present a certificate of good moral character from his last teacher or from some citizen of good standing. Students from other colleges or universities must bring certificates of honorable dismissal. Students are admitted subject to the disciplinary powers of the University authorities.

All requests for information regarding admission should be addressed to the Secretary of the University.

Collegiate Preparation Recommended

For new requirement to go into effect in September, 1914, *see p.* 19.

The liberal training offered by a preliminary Collegiate Course is quite as important to engineers, metallurgists and chemists as to lawyers, physicians or clergymen, and is strongly recommended by the Faculty of Applied Science. This, however, does not and should not involve a residence of eight years in college and technical school before a candidate receives the professional degree.

A graduate of any good college who has selected his course with reference to future work in applied science is able to complete the requirements for a degree in the Schools of Mines, Engineering and Chemistry in less than four years after receiving the Bachelor's degree. The opportunities for close articulation between Columbia College and these Schools are particularly good. Under the provisions of the new program it is possible for a well-prepared student to complete the requirements for both the collegiate and professional degrees in six years.

This six year combined course includes two years College work in English, two years in either French or German and one year each in History and Philosophy, all of these being prescribed for the College degree in addition to the courses included in the professional programs. The necessary total of College credits for the Bachelor's degree is made up by the election of four or more non-technical courses, the exact number depending on the subjects offered for admission. These should include work in Economics and according to the students' own preferences, additional work in English, History, Philosophy or modern languages (Spanish, for example), or work in Latin, Politics, or in some Natural Science not included in the professional program. In general it is better to lay a broad foundation for future professional study than to attempt the anticipation of courses which are later to be dealt with intensively in the professional program.

Requirements for Admission without Collegiate Preparation

To the First Year Class

Every candidate must offer at the entrance examinations (see below) subjects amounting to fourteen and one-half "units." A unit represents a course of five periods a week for one year in the secondary school.

Total requirement.....14½ units

The candidate must offer:

	Counting in Units
Chemistry	1
Drawing	1
Elementary French *or* Elementary German	2
English	3
Mathematics	3½
Physics	1

and three units from the following:

Elementary French *or* Elementary German	*see above* 2
Elementary Spanish	2
Elementary Latin	2
Intermediate French	1
Intermediate German	1
Ancient History	1
Modern and Mediæval History	1
American History	1
English History	1
Botany	1
Physiography	1
Zoölogy	1
Shopwork	1

Candidates for degrees of Engineer of Mines, Metallurgical and Chemical Engineer or Chemist, are recommended to offer Elementary and Intermediate German.

It is suggested that candidates deficient in entrance subjects in June arrange to take courses in them in the Summer Session of Columbia University, the announcement of which will be sent upon application to the Secretary of the University. Certain of the entrance subjects may also be pursued under the Department of Extension Teaching.

The examination requirements for admission may be satisfied by any one of the three following means, or by any approved combination thereof:

Entrance Examinations

1. By the examinations of the College Entrance Examination Board. These examinations are held annually in June, in 1913, beginning on June 16th, at Columbia University and at about one hundred and fifty other educational centers in the United States and Europe. A complete list of the places and times of such examinations, together with the regulations governing them, may be obtained from the Secretary of the College Entrance Examination Board, Post Office Sub-Station 84, New York City.

2. By the examinations conducted by the Columbia University Committee on Undergraduate Admissions. These examinations are held in September and January of each year (beginning on September 15, 1913, and January 12, 1914), and only at the University.

3. By certain of the examinations of the State Examination Board of the New York State Education Department. These examinations are held in January and June at more than six hundred high schools and other institutions throughout the State of New York, but, save in exceptional circumstances, are open only to students in those schools. Full information regarding the regulations governing them may be obtained by application to the New York State Education Department, Albany, New York.

A copy of the time-scheme of the examinations held by the College Entrance Examination Board in June, and by Columbia University in September and January, together with information as to the proper method of filing application-blanks for these examinations, the payment of fees, the division of examinations, and also detailed definitions of the requirements in each admission subject, is given in the bulletin of *Entrance Examinations and Admission* for 1913, which may be had upon application to the Secretary of the University.

A candidate may present himself at any of the series of examinations scheduled above, and the results may be credited toward the fulfillment of the requirements for admission, subject to the following restrictions:

Restrictions Governing Examinations

1. A candidate in making application for examination must submit a statement from the principal of his school, or from his last instructor, indicating the extent and character of his preparation in each subject in which he applies for examination, and credit may be withheld when this requirement is not met. The character of the school record is taken into account in determining the passing grades in the examinations.

2. The results of an examination may stand to the candidate's credit for twenty-nine months, but no longer.

3. A candidate may not present himself for examination more than four times, except by special consent of the Committee on Undergraduate Admissions.

4. The results of the examinations conducted by the New York State

COLUMBIA UNIVERSITY FROM THE WEST

Examination Board can be credited only in so far as the subject-matter of these examinations specifically covers the subjects, or lettered or numbered parts of a subject, which are accepted for admission to the Schools of Mines, Engineering and Chemistry. Candidates who have been granted the College Entrance Diploma issued by the New York State Education Department may be admitted to the Schools of Mines, Engineering and Chemistry free of conditions if the directions given on pages 8 and 9 of the Columbia University bulletin of *Entrance Examinations and Admission* have been observed. The diploma should be forwarded to the Secretary of the University together with the application for admission.

5. In order to be credited toward entrance, the reports of a candidate's examinations, together with the statement of the extent and character of his preparation in each subject offered, must be in the hands of the Committee on Undergraduate Admissions one week prior to the opening of the term in September or January.

6. The reports of all examinations must be rendered to the Committee on Undergraduate Admissions in percentages. The Committee interprets these percentages as Passed (P), or Failed (F). Credit toward admission is given only for such examinations as receive a grade of P.

Advanced Standing

The uniform first year in the Schools of Mines, Engineering and Chemistry, and the efficient coördination of the subsequent years, make it possible for graduates of colleges and scientific schools to enter Columbia University with advanced standing and to complete the requirements for a professional degree without undue delay through conflicts and other causes. It is very desirable, however, that students in other colleges who are planning to take professional work after graduation should get into correspondence with the University as early as possible. If this is done they may receive advice with regard to the most advantageous collegiate subjects to elect, and also with regard to the summer courses of Columbia University. By taking certain summer work at the University in advance, a student may sometimes save six months or a year in entering upon his professional career.

Candidates for admission to advanced standing should make application in writing to the Chairman of the Committee on Undergraduate Admissions in time to reach him on or before September 8, 1913.[1] The application must be accompanied by properly certified official statements of his standing in the subjects which he offers.

The Committee will notify the candidate at the address given in his letter, between September 8 and 12, 1913, what courses, of those offered, are accepted as equivalent to courses at Columbia University. In general, the Committee gives credit for complete courses only.[1] In

[1]When the candidate is at a considerable distance from the University, his application should, if possible, be made earlier than September in order that he may receive the reply in time to present himself at the University on September 15, 1913.

cases where the work previously done by the candidate has not been accepted by the Committee, the candidate should present himself at regular fall examinations during the two weeks immediately preceding the opening of the University (in 1913, September 15-22). For courses in which no regular fall examination is held, the candidate should report between 10 A.M. and 12 M. at the Dean's office. The schedule of fall examinations may be obtained from the Registrar.

Admission to Special Courses of Study

Graduates of these Schools, and other institutions of equal grade, may pursue any subjects taught in the schools for which they are qualified.

Persons of mature age who are not graduates, but who show special qualifications, are sometimes permitted to pursue special courses of study, but this permission is not given to others.

Except by vote of the Committee on Undergraduate Admissions no one will be admitted as a non-matriculated student who has been refused admission, or has failed in his work, as a candidate for a degree.

Persons who wish merely to pursue elementary subjects are not received as non-matriculated students.

Non-matriculated students will be held to the observance of the same regulations as to attendance, examination and proficiency as matriculated students.

Admission on Probation

Every first-year student admitted conditionally will be held under probation during the first half-year of residence. So far as possible, students on probation are given the opportunity in Columbia College or in the Department of Extension Teaching, to make good their deficiencies. Not later than the end of this period, the Dean, on the basis of reports from the head of each department in which the student is registered, will decide whether he shall be admitted to full standing, have his period of probation extended, or be dropped from the roll. The grade of B or higher, obtained in any subject at the end of the first half-year of residence, will be regarded as removing an entrance condition in that subject, unless the condition was incurred in a part of the subject not directly involved in the work of the course. Any condition not so removed must be satisfied by formal examination.

ADVICE TO STUDENTS

Each student is on entrance assigned to an officer of instruction, who acts as his academic adviser. The adviser is kept informed as to the attendance and standing of all such students in their academic work and as to the extent and character of their participation in extra-

[1]In cases where credit for part of a course might be given, the candidate should present his case to the Chairman of the Committee on Undergraduate Admissions, at the times given above, bringing drawings, note-books, or other evidence showing the scope and character of his work.

curricular activities, and he advises students on all these and other matters that concern them as students.

Reports of standing are sent to the student, his parent or guardian, his adviser and to the Dean every five weeks for students in the first and second classes, and at the end of each term for students in the third and fourth classes.

A student who has not been assigned to an adviser may apply to the Dean for such assignment.

NEW REQUIREMENTS FOR ADMISSION

To go into Effect September, 1914

Beginning with the year 1914 the curriculum of the Schools of Mines, Engineering and Chemistry will be reorganized and the requirement for admission will be increased. Three years of specialized work will be offered leading to the several degrees in Engineering and Chemistry. The requirements for admission to these schools will be completion of at least three years of a college course including thorough instruction in Mathematics, Physics, Chemistry, and, in addition, certain courses in Drafting, Shopwork, Surveying and Mineralogy.

The purpose of these changes is to provide better and broader training for students of engineering and to place the instruction in all these subjects upon the same basis as that in Law and Medicine. The rapid development of engineering practice, the wider social recognition attained by the engineering profession and the frequent demand that men in executive and administrative positions shall have an engineering training make it imperative that the engineer shall be a broadly educated, professional man. In order to insure this it is necessary that the future engineer should widen his intellectual outlook by continuing his general education beyond the termination of the high school course. Distinguished engineers among our alumni are sending their sons through college as a preliminary to entering upon professional study. At the present time nearly one hundred students are availing themselves of the opportunity to take the six-year combined college and engineering course in Columbia University.

As a suitable preparation for this advanced work, a new course has been organized in Columbia College, leading to the degree of B.S. Half the student's time is given to thorough sequential work in Mathematics, Physics, Chemistry. Most of the remainder is devoted to courses in English, the Modern Languages, History, Philosophy, and the Political Sciences, and there is some special work in Drafting, Surveying, etc., prerequisite to the professional programs. This course is so arranged that a well-prepared student should be able to complete it in three years. A student who enters college at the normal age would, therefore, be

able to complete the preliminary college course and the three years professional course by the age of 23.

Students who contemplate entering our engineering school and who, for financial, personal, or other reasons, expect to take their college work elsewhere, would do well to consult the Secretary of Columbia University for advice as to the selection and arrangement of their courses with a view to proper articulation between college work and the later professional work. Failure to do this may result in serious loss of time.

REGISTRATION

Before attending any University exercises each student must register, *i. e.*, must present himself in person to furnish the information necessary for the University records and to file a statement of the courses he is authorized to pursue (for the matriculation or registration fee, payable but once, see below).

The office of the Registrar, 201 East Hall, will be open for registration from Wednesday, September 17, to Tuesday, September 23, 1913. New students may register also on September 24. Credit for attendance will date from September 25.

Students prevented, through no fault of their own, from completing their registration in due time, should file a provisional registration blank.

Registration at a later date is permitted only to candidates who obtain the written consent of the Dean, satisfactory cause for the delay having been shown. (For the fee for late registration see below.)

Students holding scholarships are required to register not later than the date specified in the University calendar; failure to do so may be considered as vacating the scholarship.

In case of withdrawal during the academic year, students are required to file a notice thereof with the Registrar, on a blank form provided for the purpose. An honorable dismissal is granted by the Dean to any student in good standing over twenty-one who may desire to withdraw, and, with the written assent of his parent or guardian, to a student under that age. Applications for leave of absence should be addressed to the Dean.

Honorable Dismissal

FEES

The President is under instructions to withdraw the privileges of any student delinquent in payment after the second Wednesday of each half-year. All regulations as to fees are subject to change by the Trustees at their discretion.

For Matriculation or Registration: Required of all students on entrance, payable but once..... $5

For late Registration (see above)..... 5

For Changes of Registration after the second Saturday of any half-year, for any course or courses added or dropped at any one time..... 1

For Tuition in the Schools of Mines, Engineering and Chemistry, payable at the beginning of each half-year: For matriculated students for each half-year..... 125

For non-matriculated students, $7.50 per half-year for each hour of attendance upon lectures and recitations per week; with additional charges for laboratory work up to $25 per half-year when the number of hours weekly of such work does not exceed nine, and of $40 per half-year when the number of hours weekly exceeds nine; the whole not to exceed $125 per half-year.

For the use of the Gymnasium: Required of all students who do not hold an academic degree; optional for students holding such a degree..... 7

For examinations, payable in each case before the examination:

For the first examination or series of examinations (in January or September*) for admission..... 10

A single fee will ordinarily cover two consecutive series (see *Bulletin of Entrance Examinations*). The initial examination fee of $10 is credited in lieu of the matriculation or first registration fee, whenever the candidate thereafter enters the University.

For a deficiency examination or series of deficiency examinations held in the week preceding the opening of the first half-year, for each course $5, with a maximum of..... 25

For a deficiency examination at any other time than in the period designated above, whether taken at the conclusion of a course repeated by the student in addition to his normal schedule, or without such repetition, for each course[1]..... 5

For special examinations at unusual times:

For admission, for the series..... 5

For removal of deficiencies in course, for each course..... 5

For any professional degree, payable prior to filing of application[2]..... 25

*The June examinations are under the jurisdiction of the College Entrance Examination Board (see bulletin of *Entrance Examinations and Admission*).

[1] This applies to every course in which the student has already received a mark other than passing, whether such mark was reported as a failure, or merely as incomplete.

[2] Refunded to unsuccessful candidates upon application to the Registrar not later than June 20 next ensuing.

Summer Courses in Surveying, Mining and Geodesy

Laboratory fees, payable on or before the last Saturday in May, are required as follows: Civil Engineering course No. 15, $25, or $7 per survey; No. 25 and No. 27, $15, or $3.50 per survey; No. 26, $5; No. 28 and No. 71, $10.

Non-candidates, candidates for admission to, and students having entered with advanced standing, who may be required to attend these courses, and students who fail to complete them in the summer to which they are assigned, are charged in addition tuition fees as follows: No. 15, $35; No. 25, No. 27, No. 28, and No. 71, $25; No. 26, $10. Students entering with credit for part of course 15 and students deficient in separate surveys of that course shall pay a tuition fee of $10 for each survey. A tuition fee of $6 is required for each survey of courses 25 or 27 taken under similar conditions. In the case of a student registered in Columbia College who has paid an additional fee under the operation of this rule, an equitable credit will be made should he later complete the requirements for a professional degree, provided he has taken the courses at the time prescribed in the curriculum. In the case of a student admitted to advanced standing the additional fee may be refunded in whole or in part, according to regulations which may be learned from the Registrar.

Candidates for admission to advanced standing who attend the Summer Course in Practical Mining are required to pay therefor a fee of $50.

All students attending the Summer Course in Geodesy must pay a fee of $20 for the course.

Deposits for Apparatus, Supplies and for Keys to Desks and Lockers

A deposit for the use of lockers, keys, apparatus, material, and the like, ranging from $1 to $40, is required of students in Mines, Engineering and Chemistry. At the end of the academic year each student will be credited with those articles which he returns in good order, and the value of those he has injured or broken will be deducted from his deposit. Details may be obtained from the Bursar.

Residence Halls and University Commons

(See page 131)

Employment Committee

(See page 132)

Comparative Statement of Students' Probable Expenses for the Academic Year

	Low	Average	Liberal
Matriculation	$ 5	$ 5	$ 5
Gymnasium	7	7	7
Tuition	250	250	250
Books	30	45	60 up
Drafting material	2	10	15 "
Chemical apparatus	25	30	40 "
Room (37 weeks)	90	129	180 "
Board (37 weeks)	150	180	205 "
Clothes and laundry	45	100	175 "
College incidentals	2	15	25 "
Other expenses	10	25	75 "
Summer Courses in Surveying			
Laboratory	25	25	25
Travelling	5	5	5 up
Board (5 weeks)	35	35	35 "
	$681	$861	$1102

The expense for summer courses in surveying applies to all curriculums during the first summer only; for Mining and Metallurgical Engineering students during two summers; for Civil and Sanitary Engineers three summers.

RULES GOVERNING STUDENTS

1. A student cannot be a candidate for more than one professional degree at the same time.

2. A candidate for a degree must comply with all requirements in force at the time said degree is conferred.

3. A student will be permitted to substitute one subject for another provided he obtains the consent of the Dean, the heads of departments concerned and the head of the department giving the technical instruction leading to the degree.

4. A student absent from more than one-tenth of the required exercises will be debarred from examination in that subject. No student shall be exempt from this regulation except by action of the Committee on Instruction.

5. After examinations have been held, officers shall report to the Registrar the standing of all students who have attended their courses, in terms of the letters "A," "B," "C," "D" and "F." "A," "B" and "C" to be passing grades, "D" signifying a deficiency removable by re-examination, and "F" a complete failure. Reports of standing will be sent to First- and Second-year students every five weeks, and to Third- and Fourth-year students at the end of each term. Copies of all reports are at the same time sent to the Dean, to the Faculty

adviser and, in the case of First- and Second-year students, to the parent or guardian. They will be sent to the parent or guardian of Third- and Fourth-year students only on request.

6. Regular examinations shall be held at the end of the first half-year, and at the end of the second half-year in all subjects offered during those respective periods. An examination may be held at the completion of any subject which does not extend throughout the given half-year.

7. Special examinations for students deficient at regular examinations shall be held during the two weeks in September preceding the opening of the next following academic year; and for members of the fourth class in subjects belonging to that year only, during the first week in May.

Students who have been debarred and students who have received a grade of "F" are excluded from such examinations in accordance with the terms of the following rule:

Any student who shall have been debarred from or shall have received a grade of "F" in any midyear or final examination in any subject shall not be allowed to take a deficiency or make-up examination in said subject until he shall have repeated said course in class.

8. Failure to pass a Summer Session course, credit for which would be accepted as equivalent to a regular undergraduate course in the Schools of Mines, Engineering and Chemistry, shall be counted, in case a student registers for said course, as one of the three failures referred to in Rule 10.

9. The fee for special examinations is $5 for each course, which must be paid when the application is made. For special examinations in the September series the maximum fee is $25.

10. A student failing to pass in any subject at the regular examinations must present himself for special examination as provided under Rule 7.

Failing to pass the second examination, he must repeat the subject with the next class. Failing a third time to pass a satisfactory examination he may be dropped from the roll of the School.

11. Absence from any regular or special examination provided for in Rules 7 and 8 shall count as a failure unless excused by the Dean for reasons of weight.

12. No student having an entrance deficiency shall be permitted to register for any subject of the second, third or fourth year without the written consent of the Dean, and no student shall be permitted to register for any subject the prerequisites for which have not been satisfied by him unless the Dean, for reasons of weight, grants him special permission.

13. Any student who shall have passed a satisfactory examination in Columbia College in any subject forming a part of one of the professional courses in the Schools of Mines, Engineering and Chemistry will not be required to pursue that subject a second time.

14. During vacations following the close of each year, memoirs on assigned subjects must be prepared by the students in the courses of Mining, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, and Chemistry. The time specified for the completion and handing in of memoirs will be as stated in the respective departmental announcements.

A student failing to hand in his memoir, drawings or other summer work at the time specified by the department in which he is registered shall be considered to have failed; to have his work received later, he will be obliged to pay a fee of $5, as for a special examination.

15. By permission of the Dean, and concurrence of the heads of departments concerned, a student may attend subjects not required for his degree, provided such attendance does not interfere with his regular work. He must fulfill all the requirements exacted from regular students in such course.

Application for each special examination, except as provided below, must be filed at the office of the Registrar at least one week before the examination is to be taken, and in September and May at least one week before the first day of the respective examination periods (in 1913-14 not later than Monday, September 8, and Thursday, April 23, respectively). For later application an additional fee of $5 for any examination or series of examinations will be charged. Applications must be made on blanks (one for each course) to be obtained from the Registrar.

During the academic year students will be held responsible for the receipt of reports and other official communications sent to them at the coat room in University Hall. During the summer vacation they will be held responsible for the receipt of such communications sent to their home address as given on their registration blank for the preceding academic year.

SCHOLARSHIPS

Fifty scholarships of $250 each, payable in semi-annual instalments during the maintenance of a satisfactory grade, are available to students in Mining, Engineering and Chemistry who are in good academic standing, and in need of pecuniary aid. The awards are not based on competitive examinations. Scholars are not exempt from the payment of fees.

Applications for appointment or reappointment should be made on blanks furnished by the Secretary of the University, and filed with him on or before May 1.

As far as possible awards will be made not later than July 1 by the Committee on Scholarships. Scholarships not allotted at this time, or becoming vacant, may be filled by the Committee at its discretion.

In detail these Scholarships are as follows:

Open to students who have been in the University at least one year: 7 J. Pierpont Morgan, 7 Cornelius Vanderbilt, 10 D. Willis James, 1 Morris K. Jesup, 1 Samuel D. Babcock, 1 Oswald Ottendorfer.

Open to students of any class—8 Faculty, 15 Special. The Richard Butler scholarship open to students born in Ohio (for special regulations see University catalogue) has an annual value of $200.

In addition 40 Pulitzer Scholarships, carrying free tuition and a stipend of $250, are open to competition by graduates of the New York City High Schools.

Marcus Daly Scholarship in Mining Engineering

The Marcus Daly Scholarship of the annual value of $1,000, maintained by Mrs. James W. Gerard in memory of her father, is open to that worker or descendant of a worker in the Montana mines who passes the best competitive entrance examinations. The winner holds the same throughout his course in mining engineering and is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science. The next scheduled competition will be in 1915.

Class of '85 Scholarship

The class of '85 scholarship is open to duly registered students in the Schools of Mines, Engineering and Chemistry, and the holder is entitled to receive the net annual income of the class of '85 School of Mines Scholarship Fund of $8,200. The holder is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science.

Industrial Research Fellowship

An Industrial Research Fellowship was established for the year 1912-13 by the American Brake Shoe and Foundry Company of New York, for the investigation and study of materials to improve the tractive force and wearing qualities of brake shoes as used in railroad service. The work is to be carried out in the chemical laboratories of the University and in one of the plants of the American Brake Shoe and Foundry Company in Mahwah, New Jersey.

The fellowship has a value of $2,000, $1,500 of which is for stipend and $500 for the expense of materials and apparatus in connection with the investigation.

MEDALS AND PRIZES

Prize of the New Jersey Alumni Association

A prize of $50 is awarded annually by the New Jersey Alumni Association to the New Jersey student who passes the best entrance examinations to the Schools, with the proviso that before the award the student shall complete satisfactorily one half-year of academic work.

Barnard Medal

A gold medal valued at $200, endowed by President Barnard, is awarded quinquennially (next award, 1915) on the recommendation of the National Academy of Science to the person who within the five years next preceding shall have made such discovery in physical or astronomical science, or such

novel application of science to purposes beneficial to the human race as shall be esteemed most worthy of such honor. For details and for a list of previous awards see the Annual Catalogue of the University.

Illig Medals

A bequest of $2,000 by William C. Illig, E.M., '82, provides for the annual award of medals to the student or students in the graduating class of these Schools who shall, in the judgment of the Faculty, have merited the same by commendable proficiency in their regular studies.

Darling Prize

A prize in Mechanical Engineering, the income of $1,000, bequeathed by Edward A. Darling, formerly Superintendent of Buildings and Grounds, is awarded annually to the most faithful and deserving student of the graduating class in mechanical engineering, the recipient to be chosen by members of the graduating class in that Course from among three names to be chosen by the Faculty.

OPPORTUNITIES FOR ADVANCED INSTRUCTION AND RESEARCH

Special attention is called to the opportunities offered through the Faculty of Pure Science for advanced instruction and research in Mining Engineering, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, Chemistry, and Highway Engineering, leading to the degrees of A.M. and Ph.D., in accordance with the following provision: Students holding the required first degree who are primarily registered in a professional school of Columbia University, or in an allied professional school, may, with the consent of the faculty of such school, be registered as candidates for the higher degrees in the Faculty of Political Science, the Faculty of Philosophy, or the Faculty of Pure Science. In such a case the candidate must take his major subject under one of these Faculties, and must conform to all its rules as regards examinations, essay, and dissertation; but he may offer as the equivalent of four full courses for the degree of Master of Arts and of the two minor subjects for the degree of Doctor of Philosophy such of his professional courses as may be approved for that purpose by the Dean of the Graduate Faculties. A statement of the general regulations governing graduate work is printed in the *Announcement of the Faculties of Political Science, Philosophy, and Pure Science,* which may be had upon application to the *Secretary of the University.*

An outline of the courses in the Schools of Mines, Engineering and Chemistry which may be offered toward the higher degrees will be found in this Announcement on pp. 81, 87, 104, 108, *et seq.*

A separately printed pamphlet descriptive of the work in Highway Engineering may be had upon application to the Secretary of the University.

UNIFORM CURRICULUM FOR THE FIRST YEAR

The curriculum for the first year of the four-year courses leading to the degrees of Engineer of Mines, Metallurgical, Civil, Electrical, Mechanical and Chemical Engineer and Chemist is the same in every respect and the student entering the first-year class need not declare which course he will follow until the beginning of the second year, when he will have the advantage of the experience gained during the first year's work, where uncertainty exists respecting inclination or natural bent.

As will be seen in the tabular statement given below, this first year is mainly devoted to a thorough grounding in Mathematics, Physics and Chemistry, the three fundamental subjects which form the indispensable basis for all broad and successful engineering work, not only in the remaining years of the course, but throughout the entire professional career. Specialization begins to some extent in the second year and becomes more marked in the third and fourth years.

The class is arranged in two divisions, Division B completing Engineering Drafting and Descriptive Geometry in the first term, while Division A is completing General Chemistry and Qualitative Analysis, the two divisions reversing the operation in the second term. This plan secures greater concentration of work; it facilitates the transfer of students to advanced standing from other institutions; and it enables well-prepared students entering in February and taking advantage of the University Summer Session to catch up with their class by the following autumn.

To secure the most effective individual instruction the class is also divided for quizzes and recitations into six, eight, and in some cases twelve sections.

First Half Year			Hours per week	
See Page			Class	Lab'y
82	Drafting 1	Engineering Drafting	1	14
82	Drafting 3	Descriptive Geometry	3	
89	Mathematics 1	Algebra	2	
89	Mathematics 3	Analytical Geometry	3	
110	Mechanics, 1	Elementary Mechanics	2	
109	Phys. Educ. A	Gymnasium		2
110	Physics 3	Mechanics, Wave-Motion and Heat	5	
		Total..	16	16
Second Half Year				
76	Civil Eng. 2	Theory of Surveying	2	
70	Chemistry 4, 62	General Chemistry and Qual. Analysis	5	15
89	Mathematics 64	Calculus	5	
109	Phys. Educ. A	Gymnasium		2
110	Physics 4	Heat and Light	5	
		Total..	17	17

SUMMER WORK: Civil Eng. 15s. Five weeks of surveying practice.

Students who decide to elect Chemistry or Chemical Engineering have the option of taking courses Chemistry S 3C–4C in the Summer Session instead of Civil Engr. 15S.

MINING ENGINEERING

General Statement

The instruction in the School of Mines during the first and second years includes fundamental training in mathematics, physics, mechanics, chemistry, mineralogy, and geology, as outlined in the program of studies on pp. 27 and 34. Laboratory instruction in chemistry, assaying, drafting, mineralogy and geology extends through three years.

The engineering, mining, and metallurgical laboratories are equipped to train the student in the making of scientific tests of engineering materials, and working tests of machines and processes of ore treatment, thus preparing him, as far as it is possible in the school, for work that he will be called upon to do as an engineer.

Practical instruction in summer classes in the field is made an important feature of the curriculum. Details of the summer courses in mining, metallurgy, field geology and surveying will be found on pages 31, 32 and 33.

While much time is given to practical training in the laboratories, in the field, and at the mines and metallurgical establishments, care is taken to subordinate this instruction to a high standard of accomplishment in classroom work.

Advanced students and graduates can choose their subjects and plan of work much more freely than undergraduates. Suggestions as to graduate work will be found on page 112.

Location—Many coal, iron, and other mines, together with quarries and metallurgical works, are easily accessible from New York in from one to four hours by rail. Among these are magnetite iron mines in New York, New Jersey, and Pennsylvania; stone quarries in the same States, and in Connecticut; anthracite and bituminous coal mines, and natural gas and oil wells in Pennsylvania, and zinc mines in New Jersey. New York and the adjacent States produce each year about half the pig-iron and coal, and over fifty per cent. of the total value of the mineral product of the whole country. There are within easy reach of New York City iron blast furnaces and some of the most skilfully designed and managed steel works, rolling mills, steel and iron foundries, copper smelting and refining works, lead-refining works, zinc works, and electrolytic establishments in the world. New York City, moreover, is the headquarters of many corporations operating mines and metallurgical works in this and other countries. Within a radius of one hundred miles may be studied many phases of the best practice in mining and metallurgy in the country. By going a little farther one may reach the bituminous coal fields and the natural gas, oil and salt regions in one direction, and the pyrite deposits, and granite and marble quarries of New York and New England in the other;

while the excursions of the summer class in mining extend as far as the copper, iron, zinc, lead, silver, and gold regions of Michigan, Missouri, Montana, Colorado, California, Arizona and Utah (see page 32).

Building—The six-story School of Mines building is 145 feet long by 57 feet in width. The basement and sub-basement contain the ore-dressing laboratories. On the main floor are the mining and metallurgical museums and lecture rooms. On the second floor are the offices of the department of mining, the mining and metallurgical department libraries, a drafting-room for the design work of the fourth year, and one of the metallurgical laboratories. On the third floor are the offices of the department of metallurgy, the furnace rooms, the chemical laboratory, metallographic laboratory, and the research laboratories of the same department. On the fourth floor are the assay laboratories.

Equipment

Lecture Illustrations—The lectures on mining are illustrated by sets of books aggregating over 300 volumes, and containing 120,000 selected blue prints, each student having the use of books of prints for home study and for reference during the lectures. These illustrations are supplemented by an extensive set of enlarged bromide prints and other wall diagrams.

Mining Library—The University library contains complete sets of the transactions of all mining, metallurgical, and engineering societies, and of the more important periodical publications on these subjects. There is also a large collection of books on mining, and all new publications of value are added as they appear. In addition, a carefully selected departmental library is maintained, which is accessible to students at all times.

Mining Museum—The subject of mining is illustrated by collections, as follows: Maps of coal and metal mines of this and other countries. Working drawings, diagrams, and photographs of mine plant, and of mining and dressing machinery. Models of mines and parts of mines, and of mine plant. Mining tools: picks, shovels, hammers, drills, blasting apparatus, lamps, safety-lamps, anemometers; and machine drills. Ores and dressing products from typical works in this and other countries. Surveying instruments: geological compasses and clinometers, attraction compasses, dipping needles, hanging compasses and arcs, transits, lamp signals, rods, and apparatus for plumbing and measuring shafts.

Among the more notable exhibits is a large relief model of one of the mines of the Cleveland-Cliffs Iron Mining Co. of Michigan, a similar model of a typical gold mine in Colorado, and a set of three glass models and two relief models of the Copper Queen mine in Arizona, a

model of the mine workings in the Mahanoy and Shenandoah anthracite coal basins Pennsylvania, a glass model of the mine workings on the Calumet Conglomerate of Houghton County, Michigan, a model of a standard oil-well drilling rig, and a model of the St. Joseph Lead Co.'s dressing works at Bonne Terre, Missouri. There is also a collection of working drawings of mine plant, and a large collection of underground photographs, taken by magnesium light.

Mining Laboratories—These laboratories, occupying seven rooms, include the following:

The Laboratory for Mechanical Assays contains appliances for quantitative work in hand picking, jigging and vanning small samples of ore, and for panning gold-bearing gravel. For small scale working tests there are a number of specially designed laboratory classifiers, jigs, sand and slime tables.

The Crushing and Sampling Laboratory contains machinery for crushing and sampling large and small lots of ore, including gyratory and jaw crushers, rolls, a sample grinder, ball and pebble mills for fine crushing, gyratory screens, automatic samplers, and laboratory crushers, together with sieves, riffle samplers, etc.

The Laboratory for Working Tests contains an air jig, a buddle, a keeve, magnetic and electrostatic separators, and other similar apparatus for working a ton or more of ore at a time.

The Laboratory of Ore-Dressing Machinery contains full-sized machines of standard types. The apparatus now installed includes two Harz jigs of two and three compartments; a Hooper vanning jig, a Richards' pulsator jig and two pulsator classifiers, two conoidal round tables, concave and convex; a Johnston vanner, a Wilfley table, a Deister slimer, and a Stein-Bilharz belt table. On the floor below are full-sized classifiers, dewatering cones, automatic feeders, and centrifugal pumps for supplying these machines with water and ore for continuous work.

Mining Laboratory Instruction

The work required is designed (1) to illustrate the physical laws and practical conditions affecting the mechanical concentration, separation, and purification of minerals; (2) to instruct the students in the details of quantitative working tests on both small and large scale; (3) to train them in the adjustment and operation of the standard types of concentrating machines, and in testing the efficiency of such machinery in actual operation, and (4) to give opportunity for original research.

The work includes the reduction of a ton or more of ore to laboratory samples, and tests on portions of this ore by handpicking, hand jigging, and mechanical treatment on laboratory jigs, classifiers, and slime tables, to determine the proper method of mill treatment. These tests are controlled by crushing and vanning samples of the products, and reports of the results obtained are made in a systematic manner.

The large concentrators are arranged to be run continuously, for as many hours as may be necessary, using the same ore and the same water again and again. This is accomplished by running the products of the several machines through dewatering cones, from which the mixed material is transferred to the hoppers of automatic feeders. Variable speed pulleys permit any desired adjustment of the driving mechanisms. The water supply is drawn from a constant level tank fed by a centrifugal pump, and is regulated by dial cocks. Other adjustments are equally under control and can be varied at will.

With each of these machines the student makes a series of experiments. These include the adjustment and regulation of the ore supply, of the feed and wash water, of speed, stroke, and other working conditions, to the treatment of different ores and different grades of sand and pulp. In this work the student is taught to recognize the symptoms of irregular working, to diagnose the trouble with the aid of laboratory tests, and to apply the proper remedy. Incidentally he makes tests of capacity and efficiency, taking frequent samples of the ore feed, and of the different products for quantitative examination, and weighs and measures the ore and water supply and products obtained.

Experiments of this kind for purposes of instruction cannot well be made at concentration works in the field. There the machines must work regularly and without interruption, and any interference with the ore feed, water supply, or other adjustments may occasion loss of valuable mineral.

Research Work—The laboratories have facilities for original investigation in the physical laws controlling the mechanical treatment of minerals.

Original researches have recently been undertaken by graduate students in investigation of magnetic fields with reference to ore-concentration; the effect of variations in the speed of crushing machinery on the production of undersized material; the amalgamation of gold ores; an investigation of the laws of jigging.

Summer Courses

Summer Courses in Surveying—About five weeks' work in surveying is required of each class between the first and second years, and eight weeks between the second and third. See pages 44 to 47.

Summer Course in Mine Surveying—Following the 13 weeks of prescribed field work in surveying, one week is spent in underground surveying at a mine. In 1909 and again in 1910 this work was done at the Orchard Mine, Wharton, N. J.; in 1911 and 1912, at workings of No. 3 shaft, of Lehigh Valley Coal Co., Hazleton, Pa.

Summer Course in Practical Mining—Six weeks are spent in detailed study of the plant and methods of working at some mine or mines and in visits to other mines and mining regions. The course includes shaft-sinking, drifting, stoping, timbering, underground haulage, hoisting, mine drainage, ventilation, surface plant, mine buildings, repair shops, etc., organization and administration. Arrangements are made at selected mines, by which the students, singly or in small squads, may do the work described above according to a definite plan and under the general direction of the department.

These summer courses have been in operation since 1877, and have proved themselves an indispensable adjunct to the regular curriculum. They bear the same relation to the study of mining as laboratory work to the study of chemistry or physics, or clinical instruction and hospital practice to the study of medicine.

In 1909 the class of 39 students was distributed in small squads at gold, silver, copper, zinc, lead, coal and iron mines, in Colorado, Utah, Arizona, Idaho, Montana, Michigan, Missouri, Tennessee and Pennsylvania. The time occupied was from 7 to 10 weeks.

In 1910, the class, numbering 43 men, was scattered through 16 States and for the required work visited over 60 mines.

In 1911, the class numbered 40 men, who studied at gold, silver, copper, lead, zinc and coal mines, in 12 different states.

In 1912, the class of 37 men studied at gold, copper, iron and coal mines, in Colorado, Montana, Nevada, Alaska, Michigan, Tennessee, New York, Pennsylvania and New Jersey. The time occupied was from 6 to 11 weeks.

Summer Course in Metallurgy—Students are required to devote six days to the study of metallurgical plants in the vicinity of New York, where the smelting of copper and lead ore and the refining of copper and lead bullion may be seen, or the men may study metallurgical plants in the West, situated near the mines to which they may be assigned for their summer work in mining. A full report is required of each student.

Summer Courses in Geology—One week is devoted to practical field geology. The class is instructed in methods of field observation, locating outcrops, measuring dip and strike, keeping notes, etc., afterward constructing maps and geological sections from the observations noted; all under the supervision of the Professor of Geology.

ENGINEER OF MINES

The four-year course leading to the degree of Engineer of Mines is intended primarily to train men to undertake the development of mineral properties, the design and construction of mine plants, and to manage mines. It is necessarily a broad one, comprising a wide range of studies in pure and applied science, and for this reason is frequently taken by students desiring a general scientific training.

The subjects most emphasized in this course are mining, metallurgy, geology, and engineering. Metallurgy requires knowledge of inorganic and applied chemistry, qualitative and quantitative analysis, and assaying. Geology must carry with it preliminary training in crystallography, mineralogy, and petrography.

Engineering in all its branches needs a fundamental knowledge of mathematics, physics, mechanics, and thermodynamics. The proper design and construction of mining plants involves the study of certain branches of civil engineering, and the many and increasing applications of machinery to mining make it necessary to give much time to the theory and practice of mechanical and electrical engineering.

FIRST YEAR

See page 28

SECOND YEAR

	First Half Year		Hours per week	
See Page			Class	Lab'y
76	Civil Eng. 23	Theory of Railroad Surveying	2	3
82	Drafting 7	Structural Drafting		3
87	Geology 5	General Geology	3	
90	Mathematics 65	Calculus	5	
105	Mineralogy 1	Mineralogy	3	6
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
		Total..	18	14
	Second Half Year			
73	Chemistry 66	Quantitative Analysis	3	12
75	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of the Dynamo	2	
87	Geology 6	General Geology	3	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 2	Mineralogy	3	3
109	Phys. Educ. B	Gymnasium		2
		Total..	19	17

SUMMER WORK: Civil Eng. 27s and 28s, Practical Surveying (eight weeks).

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng 53	Resistance of Materials (Testing Lab.)		3
88	Geology 105	Economic Geology	3	
90	Mech. Eng. 13	Steam Power Machinery	3	
104	Metallurgy 81	Assaying	2	9
106	Mining 51	Excavation and Tunneling	3	
		Total..	16	15
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials—problem work		3
79	Civil Eng. 64	Graphic Statics	1	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
87	Geology 4	Petrography (6 hrs. for 2 months)		3
88	Geology 106	Economic Geology	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
97	Mech. Eng. 80	Experimental Mechanical Laboratory	1	3
105	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 mos.)		3
106	Mining 52	Boring & Shaft Sinking	2	
106	Mining 54	Methods of Mining	3	
		Total..	16	18

SUMMER WORK: Field work, Mining, Metallurgy, and Geology (9 weeks).

FOURTH YEAR

		First Half Year		
84	Elect. Eng. 75	Alternating Current Laboratory	1	3
88	Geology 101	Applied Petrography (elective)		
90	Mech. Eng. 17	Engineering Thermodynamics	2	
100	Metallurgy 101, 111	Introduction to Metallurgy and Metallurgy of Copper	3	
101	Metallurgy 131, 141	Electro-Metallurgy and Iron and Steel	2	
107	Mining 71	Mine Plant	3	
107	Mining 73	Mine Constructions	1	
107	Mining 75	Design of Mine Plant		12
108	Mining 81	Ore Dressing	4	
108	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
79	Civil Eng. 76	Hydraulics	2	
87	Geology 16	Paleontology (elective)		
88	Geology 102	Petrography of the Ores (elective)		
88	Geology 110	Geological Surveys	2	
97	Mech. Eng. 74	Gas Power Machinery	2	
103	Metallurgy 72	Metallurgical Laboratory (10 afts)		2
101	Metallurgy 122	Metallurgy of Gold, Silver, etc.	3	
106	Mining 56	Mine Engineering	3	
107	Mining 72	Mine Plant	3	
107	Mining 78	Thesis		12
108	Mining 80	Mill Constructions	1	
108	Mining 82	Ore Dressing (Lab.)—(afts. of 3 weeks)		3
108	Mining 94	Mining Law	2	
		Total. .	18	17

METALLURGICAL ENGINEERING

General Statement

The primary aim of the four-year course leading to the degree of Metallurgical Engineer is to train students to take administrative or laboratory positions in metallurgical works.

The undergraduate instruction consists of (1) class-room work, lectures, conferences, study of text-books; (2) general laboratory work in metallurgy; (3) training in planning and executing original research; (4) summer courses and other visits to industrial metallurgical works.

Much importance is attached to a thorough training in the fundamental subjects, mathematics, chemistry, physics, geology, mineralogy, and engineering, and to the higher branches of engineering, chemistry and important courses in mining engineering, with a view to their applications to metallurgical practice.

Great stress is laid on the original planning and executing of work, which is done under the direction and criticism of the instructors.

The instruction in metallurgy is based on the most advanced practice in the science from the introductory courses in metallurgy to the advanced special courses in the various branches of the subject.

To graduate and other *advanced students* and properly qualified *practitioners,* the department's laboratories are open under generous restrictions.

Location and Equipment

Location—For the advantages of New York and the adjacent states see page 28.

Metallurgical Establishments Accessible—Some of the most important and advanced iron, steel, copper, lead, zinc, and electrolytic works in the world are accessible to students for the study of the best metallurgical practice. See also page 98. The summer classes visit in different years metallurgical establishments in all parts of the country, including the extreme West and South.

Building—The department occupies about half the School of Mines Building. See page 29.

Collections—There are large and growing collections of lecture diagrams; of models and working drawings of metallurgical furnaces and machinery; of apparatus for lecture demonstration and illustration of metallurgical principles and processes; and a very large collection of metallurgical specimens and suites, with descriptive and explanatory notes. The metal-working shop has power-driven machines for cutting specimens, etc. Most of the furnaces are gas-fired, and those furnaces which are intended for precise work are heated by electricity.

Metallurgical Laboratories—Of these there are four. They serve four chief purposes: (1) to give skill in the use of the instruments of precision of the art; (2) to teach the underlying principles of metallurgy and give familiarity with the conditions, especially as to high temperature, under which metallurgical operations must be carried on, and the use of the principal types of furnaces and other metallurgical apparatus, or in short "Analytical metallurgy"; (3) to give some acquaintance with certain industrial metallurgical processes, or what may be called "Applied metallurgy"; and (4) to give advanced students and qualified practitioners the means of making metallurgical and metallographic researches.

Instruments of Precision—The students acquire skill with the thermo-electric pyrometer, some industrial and some autographic, with the Wanner optical and the Fery radiation pyrometer, besides which they have the opportunity of using the Mesuré and Noel (Ducretet) and the Le Chatelier optical and the Calorimetric one of Siemens. There are ammeters and voltmeters for controlling the electric furnaces; sclerometers for measuring hardness of metals and alloys; Fremont and Brinell impact testing machines; a tensile testing machine; a Berthelot calorimeter for testing fuels; and many other instruments.

Non-Ferrous and Electro-Metallurgical Laboratory—A. For wet and dry metallurgy, the extraction, refining, and alloying of the non-ferrous metals, there are ore-roasting furnaces; gas-fired crucible furnaces; assay muffle furnaces; a high temperature forge; cyanide plants; a filter press; amalgamating pans; a chlorinating barrel; ball mills; two desilverization kettles; and pyrometers. B. For electro-metallurgy, the electrical recovery, deposition, refining, and alloying of metals, there are storage batteries; a 25 K.W. motor-generator set for supplying direct current at high amperage and a range up to 15 volts; electrolytic refining vats; small electric furnaces of the Moissan arc, Borchers arc and resistance types; a 75 K.W. single phase alternating current generator and transformers for supplying current to large experimental melting, smelting, and refining furnaces of the resistance and arc types.

Iron and Steel Laboratory is equipped with electric and double muffle gas furnaces especially designed for this laboratory, in which a number of full-sized tensile test bars may be heated simultaneously to any temperature up to 1300° C., with uniformity and precision; gas and direct-fired crucible furnaces; gas forges; special furnaces; and small power-driven rolls for studying the influence of the conditions of rolling on the properties of metals.

The Metallographic Laboratories, for the miscroscopic and pyrometric study of metals, mattes, speiss, slags, ores, etc., have microscopes of the Leitz, Le Chatelier, Swift, Beck, and other types; equipment for illumination and photography; electric resistance furnaces of different types; portable gas furnaces; and pyrometers.

The Assay Laboratory has for its main equipment thirty-six gas-fired muffle furnaces, with a corresponding number of desks, which are arranged in rows with a furnace facing each desk. There are, also, a sufficient number of coke pot, coal muffle and gasoline furnaces for the student to become familiar with these types. The usual balance, grinding, and cupel rooms are provided.

Supplies—There is a large stock of ores, irons, steels, alloys, refractory materials, fluxes, etc., which may be used for investigations.

The Metallurgical Library containing about fifteen hundred volumes of metallurgical treatises, text-books, periodicals, etc., is open to all students, and to others properly introduced. Books may be borrowed under suitable restriction.

Metallurgical Laboratory Instruction

In order to become familiar with a wide range of the conditions and principles of metallurgy, the student conducts experiments, each illustrating, testing, or aiming to discover some one or more metallurgical principles or reactions, or the conditions which permit a given reaction to occur. He must, in general, after each experiment enunciate briefly in writing, the law to which his results point, or indicate how far those results severally and collectively support or oppose a given proposition.

These experiments relate chiefly to such subjects as the influence of thermal treatment on the properties and microstructure of metals and

alloys; the determination of melting points and other temperatures; the relation between the composition of mattes and slags and their fusibility; the influence of fluxes; the behavior of refractory materials at high temperatures, either alone or in contact with different slags; the temperature limits and the reactions of roasting operations; the influence of various bodies on the reactions which take place in roasting, in the cyanide process, in the chlorination process, and in pan amalgamation; the interaction of carbon and molten oxides, sulphides, silicates, etc., etc.

Summer Courses

Summer Courses in Metallurgy—No. 62s for mining engineers consisting of visits to non-ferrous metallurgical plants for a period of one week.

For metallurgical engineers the summer course lasts six weeks and includes No. 64s, visits to iron and steel metallurgical plants, and 66s, visits to plants for other metals. On these trips, which cover the practice in both the east and the west, the students are instructed in the actual metallurgical operations as carried on in the field. A prominent part of these courses consists of work such as making written descriptions of the processes, and sketches of the furnaces and other apparatus, with dimensions, usually from the student's own estimate; explaining the principles on which the processes rest, the reasons for the special shapes and sizes of the apparatus, the chief technical difficulties, how they are overcome, and by what tests the processes are controlled; giving the number of men, and, as far as practicable, the consumption of fuel and other materials, the thoroughness of recovery of the metal sought, etc. From an imaginary set of prices and wages the students have to calculate the cost and profit of certain operations.

Summer Courses in Surveying—About thirteen weeks' work in surveying is required of the class between the first and second years. See pages 44 to 47.

Summer Courses in Geology—After the third year at least one week is devoted to practical field geology. For details see page 89.

Metallurgical Excursions—At stated times excursions, open only to students in Metallurgical Engineering, are made to the neighboring foundries, machine shops, mines, and other points of interest. The students attend these excursions in squads of such size that proper individual instruction can be given to each member of the squad.

METALLURGICAL ENGINEER

This course, which covers four years, is intended for those who expect to follow metallurgical work and become trained metallurgists in any of the branches of the profession. For the first two years much attention is paid to a thorough training in fundamental subjects, especially in mathematics, chemistry, physics, geology, mineralogy, and preliminary courses in engineering. In the third year instruction in metallurgy begins both by lectures and in the laboratories, while courses in mechanical, electrical and mining engineering, chemistry, mineralogy and geology are also provided. The fourth year is devoted largely to advanced lecture courses in metallurgy and laboratory work; at the same time courses are given in the higher branches of engineering and chemistry and to important courses in mining engineering which are considered necessary.

In the summer schools instruction is given in general surveying, in railroad work, geological field work, and visits to metallurgical works are provided. In the six weeks' summer courses at metallurgical works, the students are required to study processes, make dimension sketches of furnaces and mils, and by observation and instruction they become acquainted with metallurgical operations as conducted at the time.

FIRST YEAR

See page 28

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
76	Civil Eng. 23	Theory of Railroad Surveying	2	3
82	Drafting 7	Structural Drafting		3
87	Geology 5	General Geology	3	
90	Mathematics 65	Calculus	5	
105	Mineralogy 7	Mineralogy	3	3
109	Phys. Educ. B.	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		6
		Total..	18	17
Second Half Year				
73	Chemistry 66	Quantitative Analysis	3	12
75	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of the Dynamo	2	
87	Geology 6	General Geology	3	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 8	Mineralogy	3	3
109	Phys. Educ. B.	Gymnasium		2
		Total..	19	17

SUMMER COURSES: Surveying Practice 5 weeks (Civil Eng. 27S).
Surveying Practice 3 weeks (Civil Eng. 28S).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	6
88	Geology 105	Economic Geology	3	
90	Mech. Eng. 13	Steam Power Machinery	3	
104	Metallurgy 81	Assaying	2	9
100	Metallurgy 101	Introduction to Metallurgy	1	
100	Metallurgy 111	Metallurgy of Copper	2	
		Total..	16	15
		Second Half Year		
79	Civil Eng. 64	Graphic Statics	1	3
79	Civil Eng. 78	Hydraulics	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
85	Elect. Eng. 104	Electric Distribution	2	
87	Geology 4	Petrography (6 hrs. for 2 months)		3
88	Geology 106	Economic Geology	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
95	Mech. Eng. 60	Hydraulic Laboratory		3
101	Metallurgy 122	Metallurgy of Lead, etc.	3	
105	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 months)		3
106	Mining 54	Methods of Mining	3	
		Total..	18	15

SUMMER COURSES: Non-ferrous Works Visits 3 weeks (Met. 66S). Iron and Steel Works Visits 3 weeks (Met. 64S). Geology Field Work 1 week (Geol 112S).

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	
84	Elect Eng. 75	Alternating Current Laboratory	1	3
90	Mech. Eng. 17	Engineering Thermodynamics	2	
103	Metallurgy 77	Metallurgical Plant Construction		3
101	Metallurgy 131	Metallurgy of Iron and Steel	1	
102	Metallurgy 141	Electrometallurgy	1	
102	Metallurgy 151	Constitution of Alloys	2	
103	Metallurgy 171	Metallurgical Laboratory		9
103	Metallurgy 175	Metallurgical Investigation	1	
107	Mining 73	Mine Constructions	1	
108	Mining 81	Ore Dressing	4	
108	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
71	Chemistry 122	Physical Chemistry	3	
96	Mech. Eng. 72	Gas Power Machinery	2	3
97	Mech. Eng. 76	Experimental Mech. Engineering	1	3
101	Metallurgy 118	Advanced Metallurgy of Copper	1	
101	Metallurgy 128	Advanced Metallurgy of Lead, etc.	1	
102	Metallurgy 138	Advanced Metallurgy of Iron and Steel	1	
102	Metallurgy 148	Advanced Electrometallurgy	1	
102	Metallurgy 158	Advanced Course on Constitution and Property of Alloys	1	
103	Metallurgy 172	Metallurgical Laboratory		6
108	Mining 80	Mill Construction	1	
108	Mining 82	Ore Dressing		3
108	Mining 94	Mining Law	2	
		Total..	14	15

CIVIL ENGINEERING

General Statement

The four-year course leading to the degree of Civil Engineer is designed to afford a thorough analytical training in construction and management. The course contains numerous and extended practical exercises in those matters which pertain to the profession of the civil engineer in relation to all classes of structures and public works and in connection with the various developments and applications of power by the use of steam, electric, water, and air motors. This course is also designed to be an educational preparation for those duties or functions of an executive character whose discharge in connection with the management of public or other works requires, or is rendered more efficient through, a thorough knowledge of civil engineering. The breadth and nature of this educational training adapts it no less efficiently to the purposes of those who intend to follow callings not of an engineering character but which may be related more or less to manufacturing, to structural matters, or to the development and application of power. The theoretical portion of the instruction is based largely upon the courses given in the departments of Mathematics, Mechanics, and Physics, and the results obtained are applied to practical engineering work. Special stress is laid upon the design by the student of the various structures and machines which the civil engineer is called upon to construct or operate in the practice of his profession. The instruction is given by lectures, demonstrations by the student, and frequent conferences, co-ordinate with which the work of design is continuously carried on. It covers comprehensively the subjects of surveying, road and railroad engineering, water supplies of cities and towns, irrigation, sanitary engineering, including sewage disposal, both graphic and analytic treatment of all metallic structures, foundations, retaining and reservoir walls, high masonry dams, sewer systems, hydraulic engineering, rivers and harbors, pumping engines, hydraulic, steam and electric motors.

Ample facilities are afforded for post-graduate students in civil engineering, and special students are admitted to various engineering courses of the department upon evidence of proper qualifications.

Special provision is made for graduate work in Highway Engineering and allied subjects, leading to the degree of Master of Arts designed particularly for men engaged in the practice of Highway Engineering. This work is given during the months from December to March, both inclusive, a period equivalent to one half year. Opportunity is afforded for Highway Engineers to obtain advanced professional knowledge during the season of the year when leaves of absence from work may be easily obtained.

Equipment

The school possesses an unusually full equipment of engineers' and solar transits, levels, plane tables, compasses, and all accessories, as well as smaller instruments. Current meters, hook gauges, and floats of various types are also used in making observations on the flow in, and discharge of, rivers and canals. A complete set of sections of iron and steel shapes, models and photographs of engineering works, together with working plans of the latter, are in the department for the use of students. The hydraulic laboratory affords opportunity for the practical operations of measuring the discharge through weirs and other orifices, the flow through open channels and closed pipes, frictional and other resistances in pipes and open channels, as well as for meter gaugings, and for general hydraulic investigations. The testing work in the mechanical laboratory includes the complete tests of various structural materials in tension, compression, bending, and torsion, including the observation and digesting of all corresponding data.

A cement-testing laboratory is fully equipped with testing machines, briquette molds, tanks, and other apparatus requisite for all classes of investigations in the nature and physical properties of cements and cement mortars.

A complete laboratory for the testing of road materials has been established and is constantly in use for investigations connected with materials suitable for road building. The facilities offered by the laboratory are full and sufficient to make all tests required to determine resistance to abrasion, classification of sand, gravel and broken stone and the cementing power of all qualities of road materials. This equipment also includes complete facilities with all modern apparatus used in the determination of the physical and chemical properties of bituminous materials. The laboratory is at the service of students and is used by them, both for the ordinary prosecution of studies to which the determination of results is related and for the purposes of thesis work, and other similar investigations.

The Materials Testing Laboratory is located at the north end of the main floor of the Engineering Building. It is fully equipped with modern appliances for the conduct of tests upon all structural materials. There are seven testing machines varying in capacity from 600 lbs. to 400,000 lbs., representing all American types, including a 150,000-lb. Emery hydraulic power machine, which is a standard of accuracy, and the refinement of mechanical construction. These machines are suited to make tension, compression, transverse and torsion tests upon metals, also to make all desired tests upon building materials, such as timber, stone, brick, concrete blocks or concrete-steel beams, columns, partition blocks, and all built up materials.

The laboratory is also liberally supplied with a large assortment of

extensometers, deflectometers, micrometers, gauges, and similar instruments of precision for measurement of test pieces.

Other apparatus, such as delicate scales of different sizes for use in absorption and freezing tests on building materials, also pyrometers and furnaces for the conduct of fire tests upon all kinds of fire-resisting materials are available.

General Statement of the Summer Courses in Surveying and Geodesy at Camp Columbia, Morris, Conn.

The instruction in Surveying given by the Department of Civil Engineering consists of lectures, recitations and problem work, supplemented by instrumental practice in field work, and office work in computation and mapping. The general lectures and recitations are given at the University. The field practice is given during the three summer vacations of the regular four-year course. The subject of Geodesy is given by the Department of Astronomy, and the practical work connected therewith is done under the supervision of that department by students in Civil Engineering during a portion of five weeks of the summer vacation between the third and fourth years. The theory of Plane Surveying, including Railroad Surveying, is given by the Department of Civil Engineering. The field practice is conducted under the direction of the Department at Camp Columbia, a point in the country near Litchfield, Conn., where ample facilities are provided for all requisite operations, and where the topography and climate are admirably adapted to the practical work of surveying. Five weeks' continuous attendance is required of all students in the Schools of Mines, Engineering and Chemistry during the summer between the first and second years. (See C. E. 15, page 76.) Five weeks' additional attendance is required of all students in Civil Engineering (see C. E. 25, page 76), and eight weeks of all students in Metallurgy, and eight weeks of all students in Mining (see C. E. 27 and 28, page 77), during the summer between the second and third years. Nine weeks' continuous attendance is required of all students in Civil Engineering during the summer between the third and fourth years (see C. E. 26, Astronomy 107 and C. E. 71, pages 77, 70, 79). During the summer of 1913 the Summer Courses in Surveying and Geodesy will be in session about fifteen weeks.

No student taking these courses will be excused from any part of any course on account of work done elsewhere, unless that work has been done under the immediate direction of an instructor of an institution which grants degrees in Mining or Civil Engineering. In no case will credit be given except upon the evidence of field-notes, maps, and reports presented to the Professor in charge of the courses.

Students who fail to receive a passing mark in C. E. 2 but receive

a grade of D will be allowed to take course 15, but must take the regular deficiency examination in C.E. 2 in September.

Two examinations will be held at Camp Columbia for new students and special students. The first examination will be held June 30 for students who desire to enter with Div. G, and the second one August 4, 1913, for students who desire to enter with Div. I.

The University provides houses or tents having elevated floors, furnished with cots and drafting tables. There are also provided a dining hall and bath house. Arrangements may be made for laundry work to be done in the neighborhood. A supply of drafting materials (not instruments) is kept on sale. Especial attention is given to the wholesome and substantial character of the table.

The cost of board is $6.75 per week and is charged against the individual deposits. The account against each student is reckoned from the day announced for his division to assemble. No allowances or reductions are made for absences of less than one week, and then only in the event of notice having been given and excuse granted by the officer in charge at least one day in advance of the beginning of such absence.

Each student intending to take work in these courses must notify the instructor in charge of the courses in writing before May 20, stating what course or courses he intends to take and when he will report for same. Subsequent changes in plans must be reported at once.

Every student must be present on the day appointed for his division to assemble, unless other arrangements have been made with the officer in charge. Failure to comply with this regulation may be sufficient cause to refuse the applicant's admission to the courses.

Deposits for Camp Expenses

Every student before starting for Camp, and at the same time the fees for the summer session in surveying are paid, shall make a deposit at the Bursar's office at Columbia University to meet Camp expenses, viz., board, laundry, charges for drawing material, notebooks, etc.; also to cover any damage to, breakage, or loss of instruments or Camp equipment, and transportation of self and baggage from the station to and from the Camp. The Bursar's receipt for said deposit shall be presented to the professor in charge of the summer session upon the arrival of the student in Camp.

The amounts of the deposit varies with the course or the number of courses taken and is as specified below. Students intending to take two or more courses shall deposit an amount equal to the sum total of the deposits herein specified for the respective courses. The balance of the deposit which shall remain to the credit of the student after his withdrawal from the session will be returned to him during the following October upon his application to the Bursar of Columbia University. In

case the total charges exceed the deposit the student will be subject to an additional assessment.

The deposit for C. E. 15 shall be $50; for C. E. 25, $50; for C. E. 26, $20; for C. E. 27, $50; for C. E. 28, $35; for C. E. 71, $35; and for Geodesy 107, $30.

The deposit for any one *survey* of Course 15, 25, or 27 shall be $15.

FEES

Laboratory fees, payable on or before the last Saturday in May, are required as follows: Civil Engineering course No. 15, $25, or $7 per survey; No. 25 and No. 27, $15, or $3.50 per survey; No. 26, $5; No. 28 and No. 71, $10.

Non-candidates, candidates for admission to, and students having entered with advanced standing, who may be required to attend these courses, and students who fail to complete them in the summer to which they are assigned are charged in addition tuition fees as follows: No. 15, $35; No. 25, No. 27, No. 28, and No. 71, $25; No. 26, $10. Students entering with credit for part of course 15, and students deficient in separate surveys of that course, shall pay a tuition fee of $10 for each survey. A tuition fee of $6 is required for each survey of courses 25 or 27 taken under similar conditions. (For additional information see page 21.)

Schedule of Attendance

In 1913 the School Session opens May 31 and closes September 13.

Div. A—May 31 to July 5. 5 weeks—Course 25.

Open for all 2d, 3d, 4th year students in Civil Engineering who have completed Course 15.

Div. B—May 31 to July 5. 5 weeks—Course 27.

Open for all 2d, 3d, 4th year students in Mining Engineering and Met. Engineering who have completed Course 15.

Div. C—May 31 to July 5. 5 weeks—Course 15.

Open for all 2d, 3d and 4th year students in the Schools of Mines, Engineering, and Chemistry who have not finished Course 15.

Div. D—May 31 to July 5. 5 weeks—Course 15.

Open for 20 or 25 men of all 1st year students as assigned on basis of scholarship.

Div. E—July 5 to August 9. 5 weeks—Course 25.

Open for 2d, 3d, 4th year students in Civil Engineering who reported with Div. C or Div. D for Course 15.

Div. F—July 5 to August 9. 5 weeks—Course 27.

Open for 2d, 3d, 4th year students in Mining and Metallurgy who reported with Div. C or Div. D for Course 15.

Div. G—July 5 to August 9. 5 weeks—Course 15.

Open for 1st year students as assigned from those not assigned to Div. D and of those who do not register for the summer session in New York. (Probably 75 men.)

Div. H—July 12 to August 16. 5 weeks—Course 26 C.E. and Course 107 Astronomy.

For 3d and 4th year students in Civil Engineering who have finished Course 15 and Course 25.

Div. I—August 9 to September 13. 5 weeks—Course 15.

For 1st year students as assigned from those not assigned to Div. D or Div. G. (Special dates may be arranged for those who attend Summer Session at Columbia University in New York.)

Div. J—August 16 to September 13. 4 weeks—Course 71.

For 3d and 4th year students in Civil Engineering who have finished Course 15, Course 25 and Course 51-52.

Div. K—August 16 to September 13, 4 weeks—Part of Course 25 or Course 27.

For 2d, 3d, 4th year students in Mining, Metallurgy and Civil Engineering who reported with Div. C and who withdrew with permission on July 5 to attend Summer Session at Columbia University, in New York.

Div. L—*August 16 to September 13. 4 weeks—Part of Course 15.

For special students not heretofore registered at Columbia University but who have been in attendance at Summer Session at Columbia.

Div. M—August 23 to September 13. 3 weeks—Course 28.

For 2d, 3d, 4th year students in Mining and Metallurgy who have finished Course 15, Course 27 and Course 23.

*Special students wishing to enter this course and who are not in attendance at Summer Session in New York should report August 9.

CIVIL ENGINEER

FIRST YEAR

See page 28

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
70	Botany 7	Growth and Character of Timbers	1	3
82	Drafting 5	Graphics		3
90	Mathematics 65	Differential and Integral Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
105	Mineralogy 5	Minerals of Building Stones	2	3
106	Mining 53	Excavation, Tunneling, Boring and Shaft-sinking	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physics Laboratory		3
112	Shop Work 15	Forging and Foundry Practice		3
		Total..	18	17
Second Half Year				
75	Chemistry 82	Industrial	3	
82	Drafting 6	Graphics		3
82	Drafting 8	Structural Drafting		6
83	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	*3
90	Mech. Eng. 14	Steam Power Machinery	3	
110	Mechanics 102	Analytical Mechanics	5	
101	Metallurgy 134	Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physics Laboratory		3
112	Shop Work 16	Machine-work		3
		Total..	18	18

*Saturday P.M., 1 afternoon during April and May—equivalent 1 hour.

SUMMER WORK: Practical Surveying Civil Eng. 25S—5 weeks.

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
70	Astronomy 105	Geodesy	3	
76	Civil Eng. 21	Roads, Streets and Pavements	1	
77	Civil Eng. 51	Railroad Surveying	2	3
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
78	Civil Eng. 59	Sanitary Treatment, Water Supply and Sewage	2	
78	Civil Eng. 61	Theory of Trusses	2	3
90	Mech. Eng. 17	Engineering Thermodynamics	2	
97	Mech. Eng. 77	Mechanical Laboratory	1	3
		Total..	18	15
		Second Half Year		
70	Astronomy 106	Geodesy	1	3
77	Civil Eng. 52	Railroad Surveying	3	3
77	Civil Eng. 54	Resistance of Materials (Problems)		3
78	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
90	Mech. Eng. 18	Engineering Thermodynamics	2	
97	Mech. Eng. 78	Kinematics	3	
		Total..	17	18

SUMMER WORK: { Hydrographic Surveying—Civil Eng. 26S / Geodetic " —Astronomy 107S } 5 weeks.
Railroad surveying practice—Civil Eng. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
79	Civil Eng. 75	Hydraulics	3	
79	Civil Eng. 85	Foundations	2	
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	3	
81	Civil Eng. 99	Thesis	2	
93	Mech. Eng. 41	Machine Design	1	3
95	Mech. Eng. 63	Hydraulics Laboratory		3
84	Elect. Eng. 75	Alternating Current Laboratory	1	3
85	Elect. Eng. 5	Alternating Current Engineering	1	
		Total..	18	15
		Second Half Year		
79	Civil Eng. 88	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 90	Railroad Engineering	3	3
80	Civil Eng. 94	{ Design and Construction of Sewers / River and Harbor Improvement }	2	
81	Civil Eng. 100	Thesis	3	3
85	Elect. Eng. 112	Electric Railway	2	3
89	Law 2	Business Law	2	
93	Mech. Eng. 46	Hydraulic Turbines	3	
		Total..	17	12

SANITARY ENGINEERING

GENERAL STATEMENT

The course in Sanitary Engineering is a differentiation from the regular course in Civil Engineering and naturally leads, therefore, to the same degree. The first year is identical with the first year of other engineering courses, while the second year is almost identical with the regular second-year work of the course in Civil Engineering. The special extensions in sanitary work are developed in the third and fourth years. It will be found that these sanitary subjects are set forth so as to cover in a thorough and comprehensive way those special fields occupied by the sanitary engineer of the present day. They include the sanitary treatment of water supplies and sewage with special work extended both by lectures and laboratory work into biology and bacteriology, standard laboratory methods in the sanitary administration of public water supplies, drainage, heating and ventilation and the general principles of sanitary science, public health and hygiene. These sanitary specialties are of advanced character, covering the latest investigations in such special work as daily bacterial tests of potable water for public purposes, the extermination of mosquitoes and other disease-carrying insects, the improvement of public health conditions found in cities and towns, the drainage and sanitary treatment of lands and the sanitary administration of buildings and industrial establishments liable to create nuisances. A graduate, therefore, of this course is qualified to enter the advanced practice of sanitary engineering in all its special fields.

SECOND YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
70	Botany 7	Growth and Character of Timbers	1	3
73	Chemistry 65	Quantitative Analysis	2	6
82	Drafting 5	Graphics		3
90	Math. 65	Differential and Integral Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
105	Mineralogy 5	Minerals of Building Stones	2	3
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
		Total..	18	20
		Second Half Year		
74	Chemistry 76	Microscopical Analysis		2*
75	Chemistry 82	Industrial Chemistry	3	
82	Drafting 8	Structural Drafting		6
83	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	3†
110	Mechanics 102	Analytical Mechanics	5	
90	Mech. Eng. 14	Steam Power Machinery	3	
101	Metallurgy 134	Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physics Laboratory		3
112	Shop Work 16	Bench and Machine		3
		Total..	18	16

*February and March—Microscopical Analysis equivalent to 1 hour.
†April and May—Geology equivalent to 1 hour.
SUMMER WORK: Practical Surveying C.E. 25s.—5 weeks.

THIRD YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
74	Chemistry 79	Sanitary Bacteriological Analysis	2	6
76	Civil Eng. 21	Roads, Streets, and Pavements	1	
72	Chemistry 41	Organic Chemistry	2	
77	Civil Eng 51	Railroad Surveying	2	3
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials Testing		3
78	Civil Eng. 59	Sanitary Treatment of Water Supplies and of Sewage	2	
78	Civil Eng. 61	Theory of Trusses	2	3
		Total..	16	18
		Second Half Year		
74	Chemistry 73	Sanitary Bacteriological Analysis	2	3
77	Civil Eng. 52	Railroad Surveying	3	
77	Civil Eng. 54	Resistance of Materials		3
78	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
97	Mech. Eng. 78	Kinematics	3	
		Total..	16	15

SUMMER WORK: Hydrographic Surveying, C. E. 26S—5 weeks.
Railroad Surveying Practice, C. E. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
74	Chemistry 179	Analysis of Water and Sewage		6
78	Civil Eng. 57a	Statistics and Interpretation of Water Analyses	2	
78	Civil Eng. 57b	Drainage of Marshes and Lowlands		
79	Civil Eng. 75	Hydraulics	3	
79	Civil Eng. 85	Foundations	2	
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	3	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
95	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	17	15
		Second Half Year		
74	Chemistry 180, or	Sanitary Analysis		6
80	Civil Eng. 90	Railroad Engineering	3	3
80	Civil Eng. 94	Sewers, and River and Harbor Imp.	2	
80	Civil Eng. 96	Principles of Sanitary Science, Public Health and Hygiene	3	
81	Civil Eng. 100	Thesis		6
84	Elect. Eng. 76	Alternating Current Laboratory	1	3
89	Law 2	Business Law	2	
97	Mech. Eng. 76	Mechanical Laboratory	1	3
97	Mech. Eng. 82	Heating and Ventilation	3	
		Total..	15	15

ELECTRICAL ENGINEERING

General Statement

The prescribed course leading to the degree of Electrical Engineer requires four years for its completion, and is designed for the education of those who intend to practice the profession of Electrical Engineering, either as engineers, managers, experts in industrial enterprises or as teachers in colleges or technical schools.

The instruction comprises the important branches of theoretical and applied electricity, also the fundamental and collateral subjects, which have been found by experience to be required by the electrical engineer, as, for example, mathematics, physics, chemistry, drawing, mechanical engineering, including boilers, gas producers, engines, turbines, hydraulic developments, transmission devices and shop work, also such general engineering subjects as construction in wood, masonry, iron and steel.

The graduate in Electrical Engineering is accordingly provided not only with a thorough knowledge of the principles and applications of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for the demands likely to be made upon him in connection with the practice of his profession.

The instruction is by lectures and recitations as well as by laboratory, work-shop and drawing-room practice, with periodic visits to the numerous and important electrical factories, power stations and other establishments in and about New York City.

Equipment

The offices, laboratories, museums and lecture rooms of the Electrical Engineering Department are in the southern portion of the Engineering Building. The laboratories located in the basement contain direct and alternating current machinery and apparatus. The smaller machines are mounted upon heavy tables, thus raising them to a convenient height and affording space for instruments and note-books. To further simplify the work, the machines have been assembled into unit sets, a motor being provided for each generator, so that the experimental work of one squad of students is entirely independent of that of other squads.

The direct current laboratory contains constant potential and constant current generators, motor-dynamos, as well as various types of stationary and railway motors, aggregating forty machines ranging in capacity from 1 to 35 kilowatts and of standard voltages from 115 to 550. Two 10 and two 5 k.w. generator sets with complete switchboards, carrying many measuring instruments enable various experiments to be performed by the students on the parallel operation of generators.

The constant current equipment includes a dynamo, standard switchboard and series lamp circuits. A working standardization equipment for the calibration of all measuring instruments is installed in this laboratory, and prior to any tests the students are required to check their various instruments. About eighty electrical measuring instruments are employed in this laboratory, comprising ammeters and voltmeters with various scale ranges, also speed indicators, transmission and absorption dynamometers. This laboratory is provided with a set of machine and hand tools employed in the repair of the various pieces of apparatus.

The alternating current apparatus, located in the adjoining room, comprises one single-phase alternator of 10 k.w. capacity and two three-phase alternators of 10 and 45 k.w. capacity, respectively; two 10 kilowatt synchronous motors and rotary converts operative on single-phase or two-phase circuits; two single-phase and four polyphase induction motors varying in capacity from 1 to 10 horse-power; constant potential transformers of various capacities; phase transformers for converting two-phase to three-phase currents and *vice versa;* a constant current transformer equipment of 5 kilowatts capacity with its control board, circuits and lamps; an induction regulator of 5 kilowatts and a mercury arc rectifier of the same capacity. Each of the various alternators is provided with its own driving motor, so that the speed, voltage and frequency may be altered as desired. This laboratory equipment includes a complete switchboard for the operation, control, and testing of the rotary converters used as such or as alternators; also a special polyphase circuit measuring board and about fifty instruments for the measurement of alternating voltage, current and power. The alternating current ammeters and voltmeters are of various capacities, ranging from fractional values up to 2,000 amperes and 600 volts respectively, also wattmeters up to 1,200 kilowatts range. The instrument equipment further includes several frequency indicators, synchronizers and power factor meters as well as a complete oscillograph and an ondograph for the determination of wave forms, phase relations, etc.

The lecture rooms are provided with direct-current, single-phase and polyphase electrical circuits and projection lanterns so that the lectures may be accompanied by experimental demonstrations and illustrations. The museum contains many pieces of apparatus and parts of machines used in connection with the lectures, such as specimens of pole line insulators, conduit material, rail sections, rail bonds, insulated cables and materials employed in transmission line and electric railway construction. Also various pieces of apparatus employed in telegraphy and telephony; forms of storage battery plates, samples of products obtained by electro-chemical actions, elementary electrical apparatus, etc.; pieces of electrical machinery, such as armature laminations, field

and armature coils, commutator sections, brush holders, brushes, insulating materials; small models of various types of generators and motors; numerous forms of incandescent and arc lamps, lamp mechanisms, carbons and electrodes; lightning arresters, line protecting devices and measuring instruments.

On the third floor of the building are located the large instrument laboratory, the departmental drawing-room and the studies of the officers. The laboratory contains tables upon which the various instruments are permanently set up, ready for use. These include many different forms of galvanometers, three ampere balances with scale ranges from .01 to 600 amperes, two dynamometers with ranges of 1 to 200 amperes respectively, a Standard Weston laboratory voltmeter having a range from .01 to 750 volts and a Standard Weston laboratory millivoltmeter with a set of shunts reading up to 500 amperes, Westinghouse precision watt and voltmeters and two very accurate potentiometers. The equipment further comprises apparatus for the exact measurement of resistance, inductance, permeability, hysteresis, and magnetic leakage. This laboratory is supplied with electrical energy from special sources, so that fluctuations do not cause uncertainty in the various measurements. For the direct current work special storage batteries supply potentials up to 250 volts and others have current capacity of 1,000 ampere-hours. For tests requiring small values of alternating currents a special alternator is operated. This laboratory also contains high tension testing apparatus, consisting of two 50,000 volt transformers of 5 and 10 kilowatts capacity respectively, two 10,000 volt transformers of 5 and 10 kilowatts respectively, and one 5,000 volt transformer of 5 kilowatt output. These transformers are supplied with necessary protective and measuring devices and all are designed for operation on 60 cycle circuits. This instrument laboratory is also equipped with several forms of standard integrating and recording watt-hour meters employed in connection with the standardization of consumers' electric meters for the Department of Water Supply, Gas, and Electricity of the City of New York.

The photometric testing laboratory of this Department is situated in the basement of Havemeyer Hall and is equipped with a Lümmer-Brodhun screen photometer for incandescent lamp testing, a Bunsen screen photometer with a meter prover for gas light testing and a Weber photometer, which is adaptable for arc lamp testing or for the determination of general illumination.

ELECTRICAL ENGINEER

The objects for which the regular four years' course in Electrical Engineering is designed and the education which it is intended to give are fully set forth in the "General Statement" of the Electrical Engineering Department.

The actual curriculum, including the various requirements which must be fulfilled in order to obtain the E. E. degree, are given in the following list of studies for each year, the character of each subject or requirement being explained more fully in the Departmental Statement referred to. The first two years of the course are devoted to the fundamental subjects, including mathematics, physics, chemistry, mechanics, drawing and certain electrical and mechanical engineering subjects which are elementary or introductory in character.

These fundamental and introductory subjects are intended to lay a broad and substantial foundation upon which the more specialized professional instruction of the third and fourth years is based. Even in these later years theoretical subjects, such as thermodynamics and electro-mechanics, are included and given most careful attention.

FIRST YEAR

See page 28

SECOND YEAR

See Page			Hours per week	
		First Half Year	Class	Lab'y
73	Chemistry 65	Quantitative Analysis	2	6
82	Drafting 5	Graphics		3
90	Mathematics 65	Differential and Integral Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
110	Physics 55	Physical Measurements	2	
112	Shop Work 13	Machine Work		3
		Total..	17	17
		Second Half Year		
75	Chemistry 82	Industrial Chemistry	3	
82	Drafting 6	Graphics		3
82	Drafting 8	Structural and Machine Drawing		6
83	Elect. Eng. 2	Elements of Dynamo Electric Mach'y	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
110	Mechanics 102	Analytical Mechanics	5	
101	Metallurgy 134	Metallurgy of Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physical Laboratory		3
112	Shop Work 14	Machine Work		3
		Total..	16	17
		Summer memoir.		

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 77	Hydraulics	2	
84	Elect. Eng. 101	Generator and Motor Practice	3	
86	Elect. Eng. 173	Direct Current Laboratory		6
90	Mech. Eng. 17	Engineering Thermodynamics	2	
93	Mech. Eng. 41	Machine Design	1	3
110	Mechanics 105	Thermodynamics	2	
111	Mechanics 107	Theory of Electricity and Magnetism	2	
		Total..	17	15
		Second Half Year		
82	Economics 2	Economics	3	
83	Elect. Eng. 52	Design of Direct Current Machinery	2	3
85	Elect. Eng. 104	Electrical Distribution	3	
86	Elect. Eng. 174	Direct Current Laboratory	1	6
90	Mech. Eng. 18	Engineering Thermodynamics	2	
92	Mech. Eng. 36	Kinematics of Machinery		6
97	Mech. Eng. 76	Experimental Mech. Eng.	1	3
111	Mechanics 108	Theory of Electricity and Magnetism	3	
		Total..	15	18
		Summer memoir.		

FOURTH YEAR

		First Half Year		
76	Chemistry 183	Electrochemistry	2	3
84	Elect. Eng. 103	Electric Motors	3	
85	Elect. Eng. 105	Alternating Current Engineering	3	
85	Elect. Eng. 109	Telegraphy	1	
86	Elect. Eng. 175	Alternating Current Lab.	1	6
86	Elect. Eng. 177	Instrument Laboratory	1	6
94	Mech. Eng. 53	Steam Turbines	2	
97	Mech. Eng. 77	Experimental Mechanical Laboratory	1	3
111	Mechanics 109	Theory of Alternating Current Machines	4	
		Total.	18	18
		Second Half Year		
83	Elect. Eng. 54	Design of Alt. Current Machinery	2	3
84	Elect. Eng. 98	Graduation Thesis (Optional)		
85	Elect. Eng. 106	Electric Plants	2	
85	Elect. Eng. 108	Plant Inspection	1	3
85	Elect. Eng. 110	Telephone	1	
85	Elect. Eng. 112	Electric Railways	2	
86	Elect. Eng. 176	Alternating Current Laboratory	1	6
95	Mech. Eng. 56	Hydraulic Turbines Installations	1	
95	Mech. Eng. 60	Hydraulic Laboratory		3
96	Mech. Eng. 72	Gas Power Machinery	2	3
111	Mechanics 110	Theory of Electrical Circuits	3	
111	Physics 52	Conduction of Electricity in Gases	1	
		Total..	16	18

MECHANICAL ENGINEERING

General Statement

The regular four-year course, leading to the degree of Mechanical Engineer, offers a thorough basic training in the design, construction, manufacture and operation of all classes of standard and special machinery, and their economic application to railroads, ships, mills, shops, factories and power plants, as well as in the technical and executive management of the manufacturing and transportation industries. To this end the course of instruction is as broad as is consistent with the directness of its purpose. The Mechanical Engineer must not only be grounded in the fundamental scientific basis of his profession, and so trained as to be capable of applying this to both the technical and commercial aspects of industrial problems, but his immediate usefulness upon graduation demands that a considerable portion of the instruction be concerned with the practical application of the principles taught.

The course begins with a thorough training in mathematics, physics and chemistry as a foundation for the appropriate technical work, which is developed along several parallel lines. Applications of these fundamental sciences to the physical properties of the materials of construction, especially the metals and their practical manipulation, lead through the courses in metallurgy, mechanics, resistance of materials, shop processes, the materials testing laboratory, drafting and kinematics to the principles of design, which are fixed by application to the design of machinery for the execution of any sort of process in which machinery is either absolutely essential or more economical than corresponding hand execution of the same process. The principles underlying the performance of machinery are developed by courses in thermodynamics, mechanics and hydraulics with experimental laboratory demonstration and are fixed by analysis of machinery for steam, gas and water power, pumping, compressing, refrigerating, mechanical handling of materials and their most important applications. The instruction in the performance, design and manufacture of machines and power units in the class-room and laboratory, supplemented by visits to power plants and factories, is the basis of the work on the design of plants and mills.

Throughout the instruction the student is thrown as much as possible on his own resources, encouraged to use such knowledge as he possesses, to read standard authorities and to make comparisons between the existing data on various subjects and with the results of theoretical computations. In the experimental work special stress is laid upon this as a means for the development of that initiative, execu-

tive ability and spirit of investigation so necessary for the successful practice of the profession, which is one long series of new problems demanding solution. The commercial and industrial phases of the technical subjects are dwelt upon throughout the entire course of instruction, and particular attention is given to labor and cost systems, works management, economy of manufacture and of power generation, economics and industrial law.

To insure a close contact between the work of the department and the practice of the profession, recognized experts are invited to give lectures on their particular subjects, the regular officers of the department attending and subsequently holding recitations and examinations.

For a list of special lecturers and their subjects see pages 9-12.

In addition to these regular lecturers, a list of non-resident lecturers, who deliver one or more lectures to the students on the work in their respective engineering fields will be found on pages 9-12.

The overlapping of the Mechanical Engineering and Electrical Engineering professions makes it desirable that the Mechanical Engineer shall be thoroughly conversant with the ordinary problems of the Electrical Engineer in the generation and distribution of electric current, the characteristics of electrical machinery, and the design and installation of electrical plants. To this end students in this course receive instruction in the department of Electrical Engineering covering these subjects.

Graduate work in Mechanical Engineering is offered to students who have successfully completed the undergraduate course. This graduate work includes the more difficult applications of mechanics and thermodynamics to questions of engineering, as well as special investigations in design, experimental research, and the development of new processes of manufacture. Courses are also offered to students in other departments covering such instruction in Mechanical Engineering as may properly assist in the practice of their respective professions.

Equipment

Besides the usual offices, lecture rooms, drawing rooms and museum, the department is unusually well equipped with experimental laboratory facilities. These laboratories cover a floor space of some 18,500 sq. ft. and contain apparatus valued roughly at $75,000. A fairly full line of instruments for making simple measurements is always available for regular student work, and includes thermometers, pyrometers, barometers, simple and differential manometers, draft gauges, speed counters, tachometers, angular velocity meters, planimeters, Pitot tubes, water meters of piston, rotary and Venturi type, hook gauges, steam and gas meters, steam, gas, coal and oil calorimeters, flue gas analysis apparatus,

scales for weighing and measuring, transmission dynamometers, Prony brakes, indicators of all types, pressure and vacuum gauges, anemometers, mercury columns, and calibrating apparatus for all instruments. Besides these measuring devices there is a large number of pieces of special apparatus for various purposes, such as the testing of carburetors, pressures due to explosion of gas mixtures, rate of flame propagation in explosive mixtures, pressure and temperatures of vaporization of liquid fuels, loss of head in steam, air and water pipes, condensation of steam in pipes, flow of steam or water through orifices and turbine nozzles, capacity of steam traps, flash, chill, density, viscosity and carbonization of oils, friction of bearings, losses in power transmission. These various instruments and pieces of apparatus are grouped and used in connection with a considerable number of machines of standard form. They include a standard gauge Vauclain compound locomotive, mounted on friction wheels equipped with dynamometers. This locomotive is so erected that it can be operated with its own steam, line steam or compressed air, the exhaust passing through an induced draft fan separately driven by a small steam engine. A Reynolds Allis-Corliss triple expansion engine, double eccentric type, is equipped to operate condensing and non-condensing, and is fitted with reheating receivers and may be operated with line steam or high pressure steam from the locomotive boiler. The Corliss engine has a tandem connected to three air cylinders, equipped with Gutermuth flap valves, operating three-stage with water intercoolers. A cross compound steam, two-stage air compressor of the Ingersoll-Sargent type operates in parallel with the other air compressor and with a Westinghouse simple air pump with complete air brake equipment. There is also a belt and a steam driven fan for fan investigations, together with belt and steam driven centrifugal pumps for corresponding investigation on centrifugal action of water. Besides the steam engines mentioned there are also a Westinghouse two-cylinder, single-acting; McIntosh and Seymour automatic; Sweet straight-line simple engine, besides some smaller reciprocating units, and a De Laval steam turbine, all piped to condensers for efficiency tests on wet, dry or superheated by a Foster superheater separately fired. The steam used by the engines and pumps is measured by any one of three surface condensers, Wheeler, Worthington, Allis, each with its own air and circulating pumps. The steam equipment includes also typical injectors, steam traps, feed water heaters, separators, reducing valves, safety valves, back pressure valves and other ordinary steam auxiliaries and specialties. The hydraulic work is well provided for by two large 20,000-lb. measuring tanks, fitted with swinging guide-bucket for continuous flow measurements, receiving the discharge from all the hydraulic apparatus; rectangular and trapezoidal weirs, fitted to several weir tanks, of iron and wood, three impulse water wheels, one small turbine, one hydraulic ram, simple, single and duplex steam

pumps, direct acting and flywheel, compound Blake pump, single acting, direct acting triple expansion duplex, low pressure Worthington pump of large capacity and low head, separately steam driven centrifugal Lawrence pump, belt driven centrifugal pump, a high pressure pump and accumulator of the Worthington type for 1500 lbs., and a second for 5000 lbs. pressure. Two hot air engines, and several internal combustion engines, including the Nash, fitted to operate on various fuels, a Hornsby-Akroyd and a Mietz and Weiss oil engine, an Otto, an International Harvester, a Daimler boat engine are equipped for gas engine test and investigation work of great variety. From time to time other machines are secured for short periods of time for testing purposes. For the study of refrigeration there is installed a small Brunswick ammonia compression ice-making and refrigerating unit, motor driven, and a larger De La Vergne steam-driven, ice-making plant.

MECHANICAL ENGINEER

All the subjects leading to the degree of Mechanical Engineer are listed in the following table, together with the year and term in which they are given. The first two years are devoted to essential preparatory and fundamental subjects, mathematics, chemistry, physics, analytical mechanics and drawing which are co-ordinated with kinematics, elementary design, shop work and the elements of electrical and steam engineering. In the third year there are developed the basic principles of thermodynamics, resistance of materials and hydraulics, which are fixed in the mind of the student by drill in the drafting room by design courses, in the laboratory by experiments and tests and in class by analysis of standard mechanical and electrical machinery. The fourth year is devoted to a detailed treatment of gas and steam engine design, standard water turbine characteristics and the essential relations between units constituting power plants and factories. Special attention is here paid to the economics of mechanical engineering by courses in industrial law, economics and works management. Throughout the course the aim is to develop clear conceptions of underlying principles, habits of independent thought and orderly mental procedure applicable to any sort of Mechanical Engineering problems rather than to the memorization of isolated facts. The training given not only fits the student to take up the design of machinery and the perfection of processes of doing things by mechanical means, but also to take ultimately a leading place in the management of the manufacturing and transportation industries.

FIRST YEAR

See page 28

SECOND YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
82	Drafting 7	Structural Drafting		3
90	Mathematics 65	Calculus	5	
90	Mech. Eng. 11	Steam Power Machinery	3	
92	Mech. Eng. 35	Kinematics		3
94	Mech. Eng. 59	Empiric Design	2	3
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
112	Shopwork 1	Pattern Making		6
		Total..	15	20
		Second Half Year		
75	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of Electrical Engineering	2	
90	Mech. Eng. 12	Steam Power Machinery	3	3
92	Mech. Eng. 36	Kinematics		3
110	Mechanics 102	Analytical Mechanics	5	
101	Metallurgy 134	Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physical Laboratory		3
112	Shopwork 2	Moulding and Foundry Practice		3
112	Shopwork 12	Forging		6
		Total..	15	20

SUMMER WORK: Shop Work 10s. 125 hours in College shops; Mech. Eng. 94s. 6 weeks practical work in shops and drafting rooms of manufacturing establishments, with report. A total of 9 weeks.

THIRD YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y & Draft'g.
77	Civil Eng. 53	Resistance of Materials	5	3
83	Elect. Eng. 73	Direct Current Laboratory		3
84	Elect. Eng. 101	Dynamo and Motor Practice	2	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
92	Mech. Eng. 31	Standard Tests	1	3
93	Mech. Eng. 39	Machine Design	3	3
110	Mechanics 105	Thermodynamics	2	
112	Shopwork 11	Machine Shop		6
		Total..	15	18
Second Half Year				
77	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 78	Hydraulics	2	
85	Elect. Eng. 104	Electric Distribution	3	
90	Mech. Eng. 18	Engineering Thermodynamics	2	
92	Mech. Eng. 32	Standard Tests	1	3
93	Mech. Eng. 40	Machine Design		9
94	Mech. Eng. 54	Shop Processes	2	
96	Mech. Eng. 64,	Air Machinery	2	
96	Mech. Eng. 66,	Elevators and Conveyors	1	
96	Mech. Eng. 70,	Pumping Machinery	2	
95	Mech. Eng. 60	Hydraulic Laboratory	1	3
102	Metallurgy 156	Metallographic Laboratory		
		Total..	16	18

SUMMER WORK: Mech. Eng. 96s. 6 weeks practical work in power plant, with report

FOURTH YEAR

First Half Year				
84	Elect. Eng. 103	Electric Power	2	
85	Elect. Eng. 105	Electrical Distribution	2	
91	Mech. Eng. 19	Engine Design	3	6
91	Mech. Eng. 21	Gas Power	4	3
91	Mech. Eng. 25	Steam Power	2	3
92	Mech. Eng. 33	Standard Tests	2	3
93	Mech. Eng. 45	Hydraulic Turbines	3	
		Total..	18	15
Second Half Year				
84	Elect. Eng. 76	Alternating Current Laboratory	1	3
82	Economics 2	Economics	3	
89	Law 2	Business Law	2	
91	Mech. Eng. 20	Engine Design	3	6
91	Mech. Eng. 26	Steam Power	2	6
94	Mech. Eng. 50	Steam Turbines	3	
94	Mech. Eng. 52	Organization and Management	3	
		Total..	17	15

CHEMISTRY

General Statement

The regular four-year courses of instruction herein shown are designed for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges and scientific schools, or as chemists or managers in manufacturing and other industrial enterprises.

There are two courses offered, leading to the degrees of Chemist and Chemical Engineer respectively.

Equipment

In Havemeyer Hall the Chemical Department is provided with space for its museum, lecture-rooms, and laboratories, and every convenience has been furnished for both the instructors and students working in the general or special courses.

There are five chemical lecture-rooms, all fully supplied with apparatus and instruments, the desks being equipped with pneumatic troughs, gas, pressure, exhaust, and electricity. The large chemical lecture-room on the ground floor contains 348 seats.

The Chandler Museum of General Inorganic and Organic Chemistry and of the Chemical Arts, a large room occupying the whole left wing of the ground floor, contains the elements and all their more important compounds, inorganic and organic; materials and products illustrating the chemical arts, and numerous models, pictures, and diagrams.

The new William H. Nichols Laboratories for General Inorganic Chemistry and Qualitative Analysis, together with the rooms for instructors and for research, occupy the whole of one floor of Havemeyer Hall. They are fitted up in the most modern and complete way, with all the conveniences required for instruction and investigation.

The Quantitative Laboratory has eighty-eight desks. Attached to the main laboratory is a large, well-equipped balance-room, containing accurate balances, and special rooms, provided with apparatus for gas, water, food, and electrolytic analysis.

The Organic Laboratory has forty large desks, provided with gas, water, exhaust, and electricity, and has special rooms for balances, pressure ovens, and glass-blowing.

The Laboratory of Industrial and Engineering Chemistry, for the instruction of students in practical application and the solution of problems in connection with the chemical industries, is equipped for the manufacture of pure chemicals from their raw materials on a large scale. with batteries of steam evaporators, and with steam stills, centrifugals, filter presses, crushers, vacuum dryers, multiple effect evaporators, stills and general apparatus for industrial research. It includes

a textile and paper laboratory containing a calico printing machine, paper making machinery, etc., and the regular equipment for practical research. Connected with it is a photometer-room containing a new and complete outfit for the practical testing of illuminants.

A new Laboratory for Applied Electrochemistry has been provided. The equipment consists of special motor-dynamos, one of which furnishes direct current at low voltages to the students' desks for general electrolytic work; the other provides heavy alternating current to the electric furnace room; this room is furnished with all appliances for electric furnace work. The students' desks are fitted with special switchboards and measuring instruments, and the laboratory has been arranged for carrying on research work in all branches of electrochemistry.

The Laboratory of Physical Chemistry is well equipped with the most recent apparatus adapted to a wide range of experimental work in the branches of heat, light, and electricity as applied to chemical problems.

The Chemical Library in Havemeyer Hall is supplied with an extensive collection of chemical books and journals, and is open from 9.00 A.M. to 5.00 P.M., and during the session of the University from 8.00 to 11.00 P.M.

CHEMICAL ENGINEER

The course in chemical engineering, as will be seen, is designed to educate chemists with a sufficient amount of engineering to fit them to take charge of chemical industries which depend upon the application of engineering methods and appliances to the manufacture of chemical products. This requires a knowledge of mechanical engineering, electrical engineering, hydraulics, mechanical drawing, shopwork, etc., as well as a thorough knowledge of chemistry in all its branches.

FIRST YEAR

See page 28

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Organic Chemistry	2	
75	Chemistry 81	Industrial Chemistry	3	
73	Chemistry 163	Quantitative Analysis	3	12
90	Mathematics 65	Differential Integral Calculus	5	
105	Mineralogy 15	Determinative Mineralogy		3
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
109	Phys. Educ. B	Gymnasium		2
		Total..	18	20
Second Half Year				
72	Chemistry 42	Organic Chemistry	2	
75	Chemistry 82	Industrial Chemistry	3	
73	Chemistry 164	Quantitative Analysis	3	12
83	Elect. Eng. 2	Elements of the Dynamo	2	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 16	Determinative Mineralogy		3
110	Physics 44	Physical Laboratory		3
109	Phys. Educ. B	Gymnasium		2
		Total..	15	20

SUMMER WORK: Chemistry 80a, 1 week. Shopwork 18s (8), 3 weeks in June or July.

THIRD YEAR

		First Half Year	Hours per week	
See Page			Class	Lab'y
77	Civil Eng. 53	Resistance of Materials	5	3
72	Chemistry 49	Organic Chemistry	2	9
75	Chemistry 83	Industrial Chemistry	3	
70	Chemistry 101	Advanced Inorganic	2	
90	Mech. Eng. 11	Steam Power Machinery	3	
95	Mech. Eng. 59	Empiric Design	2	3
		Total..	17	15
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 76	Hydraulics	2	
73	Chemistry 84	Food Chemistry	3	
70	Chemistry 102	Advanced Inorganic	2	
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
89	Law 2	Business Law	2	
90	Mech. Eng. 12	Steam Power Machinery	3	3
104	Metallurgy 182	Assaying	2	6
		Total..	17	15

SUMMER WORK: Chemistry 80b. Visits to Industrial Plants—2 weeks. Chemical Factory work with Report—6 weeks.

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	
74	Chemistry 171	Organic Analysis	2	6
75	Chemistry 197	Chemical Factory Machinery }		
98	Mech. Eng. 97	Mechanical Equipment of Chemical Factories }	5	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
93	Mech. Eng. 37	Machine Design	1	6
97	Mech. Eng. 77	Experimental Engineering Laboratory	1	3
100	Metallurgy 101, 111	Introduction and Metallurgy of Copper	3	
101	Metallurgy 131	Iron and Steel	1	
		Total..	18	15
		Second Half Year		
75	Chemistry 88	Industrial Laboratory		9
71	Chemistry 122	Physical Chemistry	3	3
76	Chemistry 184	Practical Electro-Chemistry	2	3
75	Chemistry 198	Chemical Factory Organization	3	
90	Mech. Eng. 18	Engineering Thermodynamics	2	
97	Mech. Eng. 76	Experimental Engineering Laboratory	1	3
101	Metallurgy 122	Metallurgy of Gold, Silver, Lead, Zinc	3	
		Total..	14	18

THE DEGREE OF CHEMIST

The course in chemistry includes not only all branches of theoretical, analytical, and industrial chemistry, but also collateral sciences, such as mathematics, mechanics, physics, mineralogy, metallurgy, electrical engineering, and drawing, which have been found by experience to be required by the professional chemist. It is the intention to provide the graduate not only with a thorough knowledge of the principles and practice of chemistry in all its branches, but with such a broad and liberal education in the collateral sciences as will prepare him for every demand that will be likely to be made upon him in connection with his profession or in the pursuit of investigation.

FIRST YEAR

See page 28

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Elementary Organic—Lecture Course	2	
75	Chemistry 81	Industrial Chemistry	3	
73	Chemistry 163	Quantitative Analysis	3	12
90	Mathematics 65	Differential and Integral Calculus	5	
105	Mineralogy 15	Determinative Mineralogy		3
110	Physics 5	Electricity	5	
109	Phys. Educ. B	Gymnasium		2
		Total..	18	17
Second Half Year				
72	Chemistry 42	Elementary Organic—Lecture Course	2	
75	Chemistry 82	Industrial Chemistry	3	
73	Chemistry 164	Quantitative Analysis	3	12
83	Elect. Eng. 2	Elements of Dynamo	2	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 16	Determinative Mineralogy		3
109	Phys. Educ. B	Gymnasium		2
			15	17

SUMMER WORK: Chemistry 80a—Memoir.

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
75	Chemistry 83	Industrial Chemistry	3	
70	Chemistry 101	Advanced Inorganic	2	
71	Chemistry 121	Physical Chemistry	3	3
74	Chemistry 171	Organic Analysis	2	6
74	Chemistry 175	Food Analysis	2	6
76	Chemistry 183	Industrial Electrochemistry	2	3
		Total..	14	18
		Second Half Year		
73	Chemistry 84	Food Chemistry	3	
75	Chemistry 88	Industrial—Laboratory Course		9
70	Chemistry 102	Advanced Inorganic Chemistry	2	
71	Chemistry 122	Physical Chemistry	3	
104	Metallurgy 182	Assaying	2	6
105	Mineralogy 10	Mineralogy and Crystallography	2	3
		Total..	12	18

SUMMER WORK: Chemistry 80b—Memoir.

FOURTH YEAR

		First Half Year		
—	Chemistry 23	Physical Chemistry } Electives,		
72	Chemistry 143	Organic Chemistry } two to be	4	
73	Chemistry 167	Adv. Inorg. Anal. Chem. } taken.		
75	Chemistry 89	Industrial Chemistry—Lab. Practice		3
72	Chemistry 141	Organic Chemistry—Advanced Course	3	
72	Chemistry, 43M	Organic Chemistry—Lab.		12
100	Metallurgy 101, 111	Introduction and Metal'gy of Copper	3	
101	Metallurgy 131	Iron and Steel	1	
		Total..	11	15
		Second Half Year		
72	Chemistry 142	Organic Chemistry—Advanced Course	3	
101	Metallurgy 122	Lead, Silver, Gold and Zinc	3	
	Thesis—			
71	Chemistry 126	Physical Chemistry } Electives,		
72	Chemistry 144	Organic Chemistry } two to be	4	
73	Chemistry 168	Adv.Inorg.Anal.Chemistry } taken.		
—	Chemistry 206	Inorganic Chem.: Research—or }		
71	Chemistry 222	Physical Chem.: Research—or }		
72	Chemistry 242	Organic Chem.: Research—or }		15
73	Chemistry 262	Analytical Chem.: Research—or }		
74	Chemistry 272	Food Chem.: Research—or }		
76	Chemistry 282	Electro Chem.: Research—or }		
		Total..	10	15

COURSES OF INSTRUCTION

Arranged Alphabetically by Departments

ASTRONOMY

105—Geodesy. 3 hours. Professor S. A. MITCHELL.

Brief history of geodetic operations and description of theodolites, base apparatus, and other instruments used in geodetic work, including their adjustment and use. Text-book: Wilson's *Topographic Surveying.*

106—Geodesy. 1 hour and 1 laboratory period. Professor S. A. MITCHELL.

The applications of practical astronomy to geodetic surveying, and training in methods of accurate computation. Text-book: Hosmer's *Practical Astronomy.*

107s—Geodetic Surveying. Professors JACOBY and S. A. MITCHELL, with Assistants.

Summer Course in Practical Geodesy: Given at Camp Columbia, Morris, Conn.
Pre-requisite for all courses: Mathematics of first two years.

BOTANY

7—Growth and Character of Timber. 1 hour and 1 afternoon. Professor CURTIS and Dr. DARLING.

Growth of the tree, character and arrangement of its tissues; relation of moisture to strength of timber; the deterioration, preservation, distribution and identification of lumber.

Second year for Civil Engineering students.

CHEMISTRY

The following courses in Chemistry are included in the programs of study of the Schools of Mines, Engineering and Chemistry. For other courses offered see the *Announcement of the Division of Chemistry.*

Inorganic Chemistry

3, 61 or 4, 62—General Chemistry and Qualitative Analysis. 5 hours class-room and 5 afternoons laboratory. Professor BEANS, Mr. LOMBARD, Dr. BARRY and Instructors.

Inorganic chemistry in advance of entrance chemistry and the theory and practice of qualitative inorganic analysis based upon the principles of modern chemistry.
Pre-requisite: Chemistry A or Entrance Chemistry.

101-102—Advanced Inorganic Chemistry. 2 lectures. Undergraduate section. Dr. ——.

Descriptive inorganic chemistry and the application of the laws and theories of chemistry and of modern views to chemical problems.
Pre-requisite: Course 163.

Summer Courses

For details, see the *Announcement of the Summer Session.*

sA—General Chemistry. Elementary course for students beginning the study of chemistry. 10 hours classroom and 12 hours laboratory work per week. Dr. MOORE.

s3c-4c—Inorganic Chemistry. Sequel to entrance chemistry. 10 hours classroom and 25 hours laboratory per week. Mr. LOMBARD.

s61—Qualitative Analysis. 10 hours lectures and conferences, and 30 hours laboratory work a week. Professor BEANS and Assistant.

Extension Teaching, Evening Courses

For details see the *Announcement of Extension Teaching.*

eA—General Chemistry. 2 lectures, 1 recitation and 2 hours laboratory practice, counting as 4 points. Dr. NEISH.

Physical Chemistry

121-122—Physical Chemistry. 3 hours lectures and recitations during the entire year, and 15 afternoons, equivalent to 1 afternoon a week, laboratory during the first or second half-year. Professor MORGAN and Assistant.

A course treating of the states of aggregation, solution, and ions in analytical chemistry, thermo-chemistry, chemical mechanics, and electro-chemistry. Text-books: Morgan's *Elements of Physical Chemistry,* and Ostwald's *Physico-chemical Measurements.*

Pre-requisite: Course 3 or 4 and 61 or 62, Physics 3-4-5 and Mathematics 64-65.

125-126—Physical Chemistry. 2 hours in lectures or conferences throughout the year. Professor MORGAN.

Designed for four-year students in the course of chemistry, selecting a thesis in physical chemistry.

222—Physical Chemistry—Research. 5 afternoons during the second half year, for students taking a thesis in physical chemistry. Professor MORGAN.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s138—Elementary Physical Chemistry. 5 hours. Professor MORGAN.

Research. The laboratory is open to properly qualified students for research under the direction of Professor MORGAN.

Organic Chemistry

41-42—Organic Chemistry, Introductory Lecture Course. 2 hours. Dr. NELSON.

An introductory course, which can be taken with advantage by college students and by those expecting to enter the medical course. Instruction given on such important classes of compounds as the hydrocarbons, alcohols, ethers, organic acids, fats, waxes, soaps, cyanides, sugars, carbohydrates, alkaloids, coloring matters, drugs, perfumes, and the like. The lectures will be liberally illustrated by material from the Chemical Museum. Text-book: Perkin & Kipping's *Organic Chemistry.*

Pre-requisite: Course 3-4 and 61 or 62. It is urged that, if possible, laboratory work, Course 43M, be taken with this course.

43M—Organic Chemistry, Introductory Laboratory Course. 4 afternoons. Drs. NELSON and FISHER.

A study of the typical methods for preparation and the typical reactions of the important classes of organic compounds. Text-book: Jones' *Laboratory Outline of Organic Chemistry.*

Pre-requisite: Courses 3 or 4 and 61 or 62. Pre-requisite or parallel: Course 41-42.

141-142—Organic Chemistry, Advanced Course. 3 lectures a week for one year. Professor BOGERT.

A discussion of the less common and of the more complicated groups of organic compounds, together with a study of the theoretical principles involved, presented in the form of select chapters from the field, and illustrated both by experimental demonstration and by material from the Chandler Chemical Museum and from the Organic Laboratory. Text-book: Richter's *Organische Chemie.*

Pre-requisite: Chem. 3 or 4, 21-22, 61 or 62, 41-42, and Prerequisite or parallel 43M.

143-144—Organic Chemistry, Conferences. 2 hours. Professor BOGERT.

Presentation and discussion of recent important investigations in the field of organic chemistry.

Required in the second half-year, of all fourth-year students in the School of Chemistry selecting a thesis in organic chemistry. Pre-requisite or parallel: Course 141-142.

49—Organic Chemistry for Chemical Engineering Students. 2 lectures and 3 afternoons. Drs. NELSON and FISHER.

The study of organic compounds and reactions with particular reference to their relation to commercial products and manufacturing processes.

Pre-requisite: Course 41-42 or its equivalent. Required of all third-year chemical engineering students.

242—Organic Chemistry, Research. 5 afternoons during the second half-year for students taking a thesis in organic chemistry. Professor BOGERT.

Summer Courses

For details, see *Announcement of the Summer Session.*

S41-42—Organic Chemistry, Elementary Lecture Course. 10 hours. Dr. FISHER and Assistant. Equivalent to 41-42.

S43-44—Organic Chemistry, Laboratory Course. Dr. FISHER and Assistant. S43-44 is equivalent to 43m.

Research. The laboratory is open to properly qualified students for research under the direction of Dr. NELSON.

Analytical Chemistry

In courses 66 *and* 163-164 *the student must provide himself with a platinum crucible.*

65—Quantitative Analysis, Inorganic, Short Course. 2 hours and 2 afternoons. Professors METZGER and Dr. McKIRAHAN.

The analyses included in this course are: Magnesium sulphate, potassium alum, coal, iron ore, copper, zinc, alkalimetry, acidimetry, and flue gas.

Pre-requisite: Courses 3 or 4 and 61 or 62.

66—Quantitative Analysis, Inorganic. 3 hours and 4 afternoons. Professor METZGER and Messrs. BENDER, ISHAM and McKIRAHAN.

The analyses included in this course are: Magnesium sulphate, iron-ammonium alum, coal, iron ore, pig iron, zinc ore, limestone, slag, copper and lead ores, and flue gas.

Pre-requisite: Courses 3 or 4 and 61 or 62.

163-164—Quantitative Analysis. 163—3 hours and 4 afternoons. Professor METZGER and Messrs. BENDER and ISHAM.

The classroom work includes not only the methods applied in the laboratory, but discussions of quantitative separations from a theoretical standpoint, and chemical calculations. Text-books: Treadwell's *Quantitative Analysis* and Miller's *Calculations of Analytical Chemistry.*

The analyses included in this course are: Magnesium sulphate, sodium or other chloride, potassium alum, iron ammonium alum, coal, iron ore, pig iron, spiegel, limestone, ores of zinc, copper, nickel, lead, arsenic, alloys, rocks, gas analysis, etc.

Pre-requisite: Courses 3 or 4 and 61 or 62.

167-168—Advanced Inorganic Analysis. 2 hours. Professor METZGER.

A systematic study of the separation and determination of the elements, including the rare elements.

Pre-requisite or parallel: Chemistry 101-102, 121-122, 163-164.

262—Analytical Chemistry, Research. 5 afternoons during the second half year for students in the course of Chemistry, who elect thesis work in inorganic analytical chemistry. Professor METZGER.

Summer Courses

For details see the *Announcement of the Summer Session.*

s66—Quantitative Analysis. 5 lectures and 30 hours laboratory work weekly. Mr. BENDER and Assistant.

s164—Quantitative Analysis, Advanced. 5 lectures and 30 hours laboratory work weekly. Mr. BENDER and Assistant.

Food Chemistry

84—Food Chemistry. 3 hours. Professor SHERMAN.

The general principles of food chemistry and food legislation and the chemical technology and control of the more important food industries; milk and its products; meat products; edible fats and oils; grain products; starch, glucose, sugar; fruit products; fermentation; etc.

Pre-requisite: Chemistry 3 or 4 and 81-82 or 41-42.

171—Organic Analysis. 2 hours and 2 afternoons. Professor SHERMAN and Mr. THOMAS.

The lectures include general and industrial organic analysis, fertilizer analysis and inspection, examination of drinking water. Special attention is given to the interpretation of the analytical results. Text-books: Sherman's *Methods of Organic Analysis* and Mason's *Examination of Water.*

The analyses included in this course are: Acidimetry and alkalimetry, alcohol, sugars, lubricating and other industrial oils, soap, fertilizers, and the sanitary analysis of water.

Pre-requisite: Chemistry **41-42** and **161-162.**

175—Food Analysis. 2 hours and 2 afternoons. Professor SHERMAN and Mr. THOMAS.

The class-room work of this course includes a discussion of the descriptive and analytical chemistry of the principal constituents of foods, and some of the more important enzymes connected with the utilization of foods, as well as the analysis of commercial food products. Special attention is given to the interpretation of the results of food analysis in relation to official standards of composition and purity. Text-book: Sherman's *Methods of Organic Analysis.*

The analyses included in this course are: Sugars, starches, cereals and bread-stuffs, edible oils, butter, milk, and food preservatives.

Pre-requisite: Chemistry **41-42** and **161-162.**

272—Food Chemistry, Research. 5 afternoons during the second half-year for students taking a thesis in Food Chemistry. Professor SHERMAN.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s175—Food Analysis. Professor SHERMAN and Mr. THOMAS.

s176—Chemistry of Food and Nutrition. 3 hours. Professor SHERMAN. (Will be accepted as equivalent to Chemistry **84.**)

Research. The laboratory is open to properly qualified students for research, in organic analytical chemistry or the chemistry of foods, under the direction of Professor SHERMAN.

Sanitary Analysis

76—Microscopical Analysis. Laboratory and conference, 2 hours a week during February and March. Mr. ——

Construction, use and care of the microscope. Examination and identification of common fibres, starches, spices, yeasts and other objects of economic importance. Common adulterants. Measurement of sand grains, micro-organisms, etc.

Pre-requisite: Chemistry **65.**

78—Sanitary Biological Analysis. 2 hours and 1 afternoon laboratory a week, for first term. Mr. ——

General principles of biology, biological activity-function, metabolism, symbiosis, etc.; special biology-unicellular animals and plants—causes of tastes, odors, and turbidity in drinking water.

Pre-requisite: Chemistry **65, 76.**

79—Sanitary Bacteriological Analysis. 2 hours lectures and 2 afternoons laboratory work, first half-year. Mr. ——

Practical instruction in bacteriology and hygiene. A short course for sanitary engineering students.

Pre-requisite: Chemistry **65, 76.**

179—Analysis of Water and Sewage. 2 afternoons, first term. Mr. ——

Physical, chemical, microscopical and bacteriological methods.

180—Sanitary Analysis. Advanced methods and special problems. Second term, 2 afternoons. Mr. ——

Industrial Chemistry

81-82—Industrial Chemistry, General. 3 hours lectures. Professor WHITAKER, Mr. MURPHY and Instructor.

Air; water; sulphur; sulphuric acid; nitric acid; hydrochloric acid; alkali industries; potash; artificial gases and natural gas; petroleum and its products; cement; paints and varnishes; soaps; ceramics; glass; explosives; fuels; structural materials.

Pre-requisite: Courses Chemistry 3 or 4 and 61 or 62.

83—Industrial Chemistry, Advanced Course. 3 hours. ——

Textile; tanning; glue and gums; India rubber and plastics; celluloid; artificial fibers; paints, oils, varnishes; paper; photography, etc.

Pre-requisite: Courses Chemistry 3 or 4 and 81-82 or 41-42.

88—Industrial Chemistry, Laboratory Practice. 3 afternoons. Professor WHITAKER, Mr. MURPHY and Instructor.

Fourth-year students in Chemical Engineering.

89—Industrial Chemistry, Textile and Dye Chemistry. 1 afternoon. ——

Special applications: Textile industry, vegetable and animal fibres, bleaching, dyeing, and calico printing. Including instruction in the use of the microscope.

Pre-requisite: Course 3 or 4, 41 or 42.

197—Chemical Factory Apparatus and Machines. 5 hours. Professors WHITAKER and THOMAS.

To cover the construction and use of the apparatus and machinery of chemical factories.

198—Chemical Factory Management. 3 hours. Professor WHITAKER.

Relations of the chemist to the various phases of making and marketing chemical products. Sales organization and methods; transportation of products and materials; purchase of supplies; warehousing and stocks; manufacturing organization; equipment; process; operation; cost keeping and accounting; process improvements; product improvements; factory economics; labor; insurance; fire and accident protection; finance; administration.

80a—Factory Inspection and Summer Memoir. Professor WHITAKER, Mr. MURPHY and Instructor.

Visiting and inspection of chemical works of special interest in and near New York City, such as gas works, petroleum refineries, paint and varnish factories, soap and candle works, and plants for the purification of water and sewage.

Required of all second-year students in the courses of chemistry and chemical engineering. The visits to factories are made during the weeks following the final examinations.

80b—Summer Factory Excursion Work and Report. Professor WHITAKER and Instructors.

Two weeks is devoted to a study of industrial plants in New York and neighboring cities. Students will also be required to work at least six weeks in a chemical factory or laboratory or in some position approved by the instructor. Full report on this requirement will be made to the instructors at the conclusion of the work.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s81—Industrial Chemistry, General. 5 lectures per week. Mr. ISHAM.

Electro-Chemistry

181-182—Practical Electro-Chemistry. 10 hours. Professor TUCKER.

Electroplating, influential factors in electrolysis, the use of diaphragms, electrolysis of fused salts, electrolytic preparations, metal refining, electric furnace

practice, and preparation of carbides, silicides, etc., measurement of high temperatures.

Pre-requisite: Courses 3 or 4, 61 or 62, 65.

183-184—**Industrial Electro-Chemistry.** 2 hours and 14 afternoons. Professor Tucker.

The applications of electrolysis and the electric furnace to the production and purification of chemicals and metals. Illustrated by short laboratory course.

Pre-requisite: 3 or 4, 65.

282—**Electro-Chemistry, Research.** 5 afternoons during the second half-year for students taking a thesis in electro-chemistry. Professor Tucker.

CIVIL ENGINEERING

2—**Theory of Surveying.** Lectures and recitations, 2 hours. Professor Lovell, Mr. Finch and Assistants.

Methods of measuring angles and distances. Cumulative and compensating errors, and corrections to be applied. Limits of precision. Use, care, and adjustment of the engineer's transit, level, and compass. Magnetic declination and variation. Local attraction. Relocation of old lines by compass bearings. Erroneous standards. Surplus and deficiency. Significance of monuments. Traverses; computations of area and error of closure. Laying out and dividing up land. System of public land surveys. Topographic surveys; transit stadia and plane table methods. Triangulation. City surveying, subdivision and resurveys. Interpretation of deed descriptions. Text-book: Tracy's *Plane Surveying.*

For all first-year students in Chemistry.

15—**Surveying between the First and Second Years.** Field work and office work. 5 weeks. 4 surveys. Professor Lovell, Mr. Finch and Assistants.

Survey 1 includes pacing and chaining, ranging out lines, contouring with hand level, mapping. *Survey 2* consists of the adjustment of the level and in running a line of differential levels. Note book and report. *Survey 3* consists of the adjustment of the transit, angle reading by repetition, determination of stadia constant, observations to determine reliability of the compass, the survey of a closed field or farm, measuring the boundary lines by steel tape and the angles or directions by transit and locating the principal topographic details by stadia. Notebook, computation of area and map. *Survey 4* consists of repetition traverse of a closed field, distances being measured by steel tape corrected for catenary, pull, and temperature. Determination of magnetic declination by observation on Polaris.

Pre-requisite: 2.

21—**Highway Engineering.** 2 hours. Professor Lovell.

Road resistances—Design, construction, maintenance and repair, of Dirt, Gravel, Broken Stone and Miscellaneous Roads—Street Location—City pavements—Belgian and Granite Block, Brick, Asphalt and Wooden Block—Foundations—Grades—Drainage, Specifications. Reference and text-books: *Roads and Pavements,* Baker.

23—**Theory of Railroad Surveying.** 2 hours and 1 afternoon. Professor Lovell and Mr. Finch.

An abridged course, for students in Mining Engineering, covering the same subjects as are taken in Course 51-52.

Pre-requisite: 15.

25—**Surveying between the Second and Third Years.** Field work and office work. 5 weeks. 5 surveys. Professor Lovell, Mr. Finch and Assistants.

Survey 1 consists of running a line of levels for a water main or sewer, plotting profile, and computation of excavation. *Survey 2* consists of a topographic survey with plane table. Intersection, re-section, and traverse methods to be used, and

map made. *Survey 3* consists of a topographic survey with transit and stadia; note-book and map. An optional course in photographic surveying may be offered in 1912. *Survey 4* consists of solar observations with transit and solar compass for the determination of the true meridian and magnetic declination. *Survey 5a*, City surveying, consists of the division of land into city blocks and subdivision into lots and the location of the street and lot lines; grade lines for streets and grades at street intersections; location and grade of sewers; including map, profile, and computation of excavation for street opening and sewer line. Relocation of lot lines and problems in surplus and deficiency, map showing property with record line and encroachments. Location of lines for buildings, bridge abutments, etc.

Pre-requisite: 15.

26—Surveying between the Third and Fourth Years. Hydrographic Survey. Field and office work. 2 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Survey made in conjunction with Geodetic Survey (total time 5 weeks, see page 70, Dept. of Astronomy), which furnishes main triangulation net for topographic and hydrographic control. Hydrographic survey consists of auxiliary triangulation, topography on shore by stadia, soundings, observations on outlet by current meter for river discharge, adjustment of angles, computation of triangulation system, also of river discharge, map and report.

Pre-requisite: 25.

27—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Professor LOVELL, Mr. FINCH and Assistants.

Same as C. E. 25 except *Survey 5a* is omitted and *Survey 5b* is added. *Survey 5b* consists of the location of a mining claim 1,500 feet long by 300 feet wide in conflict with existing claims, and the determination of the areas in conflict. The claim is located upon an outcrop of assumed dip and strike, in such a manner as to keep the center line close to the outcrop. Reports and maps.

Pre-requisite: 15.

28—Surveying between the Second and Third Years. Field work and office work. 3 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Railroad surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computation—Economic comparisons from construction and operating standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, calculations of earthworks, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 23, 27.

51-52—Theory of Railroad Surveying. 2 hours and 1 afternoon, first half-year, and 3 hours and 1 afternoon second half-year. Professor LOVELL and Mr. FINCH.

Simple, compound, and reversed curves—Transition curves—Switch work—Cross-section work—Earthwork computations—Cost of earthwork; cut and fill—Borrow—Waste and overhaul—Office work; Profile with mass curve showing proper distribution of excavation. Lectures and practical problems. Reference books: Searle's *Field Engineering* and Crandall's *Transition Curve and Earthwork.*

Pre-requisite: 15.

53-54—Elasticity and Resistance of the Materials of Engineering. 5 hours lectures and recitations first half. 6 hours first half-year of problem, design and laboratory work; 3 hours second half. Professors BURR and NORSWORTHY, Mr. MACGREGOR and Mr. ——.

Laws of elasticity in homogeneous materials—Coefficients of elasticity—Relations between stresses and strains—Common and exact theories of torsion and flexure—Elastic limits, working stresses, and ultimate resistances of wrought iron, cast iron, steel, alloys, timbers, building-stones, cement, concrete, and masonry—Reinforced concrete construction—Complete treatment of simple and continuous beams—The

design and construction of iron, steel, and timber columns and beams, including the design and construction of plate girders—Shafts—Cables—Fatigue of materials—Specifications—Testing Laboratory—Discussion of properties of structural materials as shown by results of testing, by tension, compression, bending, and torsion—Report of tests. Reference and text-book: Burr's *Elasticity and Resistance of Materials.*

Pre-requisite: Mechanics 102.

57a—Statistics and Interpretation of Water Analyses. 20 lectures.

Collection, preparation and interpretation of vital statistics, for the identification of the sanitary condition of particular States, cities, or communities as affected by water and milk supplies, sewerage systems, industrial and economic conditions. Interpretation of complete water analyses.

57b—Drainage of Marshes and Lowlands. A course of 10 lectures.

Mosquitos, habits, breeding, methods of extermination. Malaria, yellow fever.

Pre-requisites for courses 57*a* and 57*b* are Zoology **7**, Bacteriology **101**, and Civil Engineering **59**.

58—Masonry Structures. 3 hours and 1 afternoon with frequent conferences and continuous work in design. Cement and mortar testing in the cement-testing laboratory are required of all students. Professor NORSWORTHY.

Pressure and abutting power of earth—Design and construction of retaining walls—Stability of masonry structures in general—Stability of towers and chimneys under wind pressure—Theory and design of arches with vertical and inclined loads—Theory and design of reservoir walls, earth and high masonry dams—Theory and Design of masonry domes—Cement, concrete, and masonry. Reference books: Ketchum's *Walls, Bins and Grain Elevators;* Morrison and Brodie's *High Masonry Dams,* and Baker's *Masonry and Foundations.*

Pre-requisite: Mechanics 102, Mineralogy 5.

59—Sanitary Engineering. 2 hours and 2 afternoons in January in Bacteriological Laboratory. Professor JACKSON.

Treatment and disposal of sewage and refuse of manufacturing—Sedimentation by gravity and by chemical precipitation—Treatment of effluent by continuous and intermittent sand filtration—Septic tanks—Contact beds—Percolating or trickling filters—Continuous flow tanks—Fertilization—Intermittent application to soil with under-drainage—Disposal of sludge—Plants for sewage treatment—Theory and construction of sand filters—Pollution of potable water and its purification by continuous and intermittent sand filtration—Mechanical filtration—Copper sulphate, ozone and other treatment for special waters—Design of sand filter for water purification—Examinations of and reports on typical purification works. Biology and Bacteriology of drinking water. Text-books: *Filtration of Public Water Supplies,* Hazen; *Purification of Sewage,* Kinnicut, Winslow and Pratt.

Pre-requisite: Chemistry 82.

61—Analytical Theory of Trusses. 2 hours and 1 afternoon, with frequent conferences and problems in computations of stresses and preparation of stress sheets. Professor NORSWORTHY.

The truss element—Simple cantilever and non-continuous trusses with parallel chords—Fixed and moving loads—Through and deck spans—Positions of any system of concentrated moving loads for greatest chord and web stresses when chords are both parallel and non-parallel—Combination of moments and graphic methods—Skew and irregular trusses—Applications to bridge and roof trusses—Braced arches and arched ribs. Reference and text-book: Burr and Falk's *Metallic Bridges.*

Pre-requisite: Mechanics 102.

62—Graphic Statics. 2 hours and 1 afternoon. Professor NORSWORTHY.

For students in Civil Engineering—Equilibrium polygon, and polygonal frames for all systems of loads—Graphical representations of shears and moments for both non-continuous and continuous beams—Fixed and moving loads—Lines of influence

—Applications to bridge and roof trusses. Reference and text-book: Burr and Falk's *Influence Lines.*

Pre-requisite: Mechanics 102.

64—Graphic Statics. 1 hour and 1 afternoon for mining engineers and metallurgist. Professor NORSWORTHY.

An abridged course, covering the subjects taken in Course 62.

Pre-requisite: Mechanics 102.

71—Surveying between the Third and Fourth Years. Field work and office work. 4 weeks. Professor LOVELL, Mr. FINCH and Assistants.

Railroad Surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computations—Economic comparisons from construction and operation standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, earthwork quantities, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 51-52 and 25.

75—Hydraulics. 3 hours, with conferences and problems. Mr. FINCH.

Hydrostatics—Laws of hydraulics—Measurement of head, pressure and flow—Gages—Manometers—Venturi meter—Current meter—Flow through orifices—Weirs, use, construction and discharge—Flow and discharge of pipes—Compound Pipes and branches—Flow in and discharge of open channels—Canal design—Stream gaging by current meter, floats, etc.—Graphical solution of hydraulic problems—Backwater—Elements of flow of compressible fluids. Text-book: Merriman's *Hydraulics.*

Pre-requisite: Mechanics 102, Math. 64-65.

76—Hydraulics. 2 hours. Mr. FINCH.

For students in Chemical and Mining Engineering—Course 75 abridged.

Pre-requisite: Mechanics 102, Math. 64-65.

77—Hydraulics. 2 hours. Mr. FINCH.

For students in Electrical Engineering—Similar to Course 75, but shorter. In addition it deals with the general considerations of rainfall, evaporation, percolation, run-off, net yield and storage; conduction of water from source to power-house, hydraulic losses and effective head on wheel; estimation of power. Text-book: Merriman's *Hydraulics.* Reference book: Turneaure and Russell's *Public Water Supplies.*

Pre-requisite: Mechanics 102, Math. 64-65.

78—Hydraulics. 2 hours. Mr. FINCH.

For students in Metallurgical and Mechanical Engineering—Same as 76.

Pre-requisite: Mechanics 102, Math. 64-65.

85—Foundations. 2 hours, with frequent conferences and work in design. Professor BURR.

Earth foundations—Foundations for buildings—Safe loads on masonry and foundation beds—Pile driving and pile foundations—Safe loads for piles—Protection and preservation of piles and timber—Sheet piling and coffer-dam methods—Pneumatic foundations and caisson work—Open dredging—Bridge piers of masonry and cylinders—Piers for deep foundations—Methods of working in quicksands—Tunneling. Reference books: Patton's *Foundations* and Baker's *Masonry and Foundations.*

Pre-requisite: 58, Geology 18.

87-88—The Design and Construction of Bridges, Roofs, and Buildings. 2 hours and 1 afternoon, with frequent conferences and continuous work in design. Professors BURR and NORSWORTHY.

Railway and highway bridges—Pin and riveted connections—Single and multiple system of bracing—The design of details for bridges, roofs, and buildings—Floors

for railway and highway bridges—The design and operation of draw-bridges, including engines, locking, lifting, and turning machinery—Cantilever structures—Wind roads and stresses—Single and double-track viaducts or trestles in iron, steel, and timber—Lateral and transverse systems of bracing—The design and construction of elevated railroads—The complete designs of railway structures, with estimates of cost—The erection of iron, steel, and timber structures, including the cost of erection. First half-year only for sanitary engineers. Reference and text-books: Burr and Falk's *Influence Lines;* Burr and Falk's *Metallic Bridges.*

Pre-requisite: 53-54, 61-62.

89-90—Railroad Engineering. 3 hours and 2 afternoons for conferences and design work. Professor LOVELL and Mr. FINCH.

Location, construction and operation—Train resistance, sources and probable value—Curvature and grades, their relation to velocity and maximum train-load—Effect of momentum—Reduction of grades at starting points—Balance of grades for unequal traffic—Study of annual reports—Analysis of operating expenses—Cost of operating, including maintenance, per train mile—Itemized statements of costs and percentage to total cost—Cost of extra distance, curvature, rise and fall, or of additional trains—Effect of roadbed on cost of running trains—Justifiable expenditure in construction to save one mile of distance, one degree of curvature, one foot of rise and fall, or to reduce ruling grade .1% per daily train per year—Pusher grade for one or more assistant engines—Economical use of pusher grades—Cost of excessive or limiting curvature—Value of additional traffic—Principles to follow in locating new lines—General policy of improvements in old lines—Principles in design and construction of railroad yards and terminals—Computations and detail drawings of turnouts, slip switches and ladder tracks—Development and present practice in block signalling and interlocking, with problems in design and estimates of cost of installation—Classification and cost of earthwork—Graduation, cross section in excavation and embankment, and protection of slopes—Ordinary and extraordinary methods of drainage—Water supply, its quality, storage, and delivery—Design of standard maintenance of way plans, including ballast—Track and track accessories—Organization—Management. Reference books: Wellington's *Railway Location*—*Elements of Railroad Engineering,* Raymond—*American Railway Transportation,* Johnson—*Railway Signaling,* Latimer—Camp's *Notes on Track*—Dewsnap's *Railway Organization and Working.*

Pre-requisite: 71.

94—The Design and Construction of Sewers, and River and Harbor Improvements. 2 hours lectures, recitations, problem and design work. Professor NORSWORTHY.

Sewerage and surface drainage of cities and towns—Separate and combined systems of sewers—Capacities of mains and branches—Catch basins—Manholes—Chimneys or ventilators—Flush tanks—Outfalls—Grades—Flow or discharge of sewers—Construction. River and Harbor Improvements—Jetty system of river improvements—Scouring action of currents—Erosion of river banks—Dams for improvement of river navigation—Breakwaters—Dykes—Groins—Mattress work—Docks—Harbor works—Iron piers—Estimates of cost. Text and reference books: *Separate System of Sewerage,* Staley and Pierson—*Sewer Design,* Ogden—*Flow of Water in Open Channels, Pipes, etc.,* Flynn.

Pre-requisite: 26, 59, 75.

96—Principles of Hygiene, Sanitary Science and Public Health. 3 hours.

Health and disease; the germ theory of disease; dust and its dangers; infection and contagion; drinking water, ice, milk, vegetables, shell-fish, etc., as vehicles of disease; flies, fleas and other disease carriers; general problems of public health and sanitation. Personal hygiene.

Pre-requisite: Civil Engineering 57*a* and 57*b*, Zoology 7, Bateriology 101, C. E. 59.

97—Water Supply, Water Power and Irrigation. 3 hours lectures, recitations, problem and design work. Mr. FINCH.

Water Supply—General problem—Quantity required—Detection and prevention of waste—Metering—Methods of supply—Rainfall, run off and flood flows—Storage—River and lake intakes—Underground flow and wells—Gravity supplies—Storage reservoirs—Aqueducts and pipe lines—Equalizing reservoirs—Pumping—Elevated tanks and standpipes—Distributing system—Operation, construction and maintenance—*Water Power*—The hydrograph—Relation of load curve, pondage, etc.—Effect of flood flows on head—Flashboards—Construction—*Irrigation*—Extent—Duty of water—Elements of design—Reservoirs—Headworks—Canals and flumes—Applica-

tion of water. Reference books: *Public Water Supplies*, Turneaure and Russell —*Water Power Engineering*, Mead—*Irrigation Engineering*, Wilson.

Pre-requisite: 26, 59, 75.

99-100—**Graduation Thesis.** A project or thesis on some civil engineering subject, approved by the head of the department, is required of every candidate for the degree of Civil Engineer.

Advanced Courses

The advanced courses in the department of Civil Engineering qualifying for the University degrees of Master of Arts and Doctor of Philosophy (those courses which fulfill the residence requirements) are the following:

153-154—**Elasticity and Resistance of Materials.** Half course.

257-258—**Elastic and Masonry Arches.** Open to those who have taken 57-58. Conferences, reading and design work, as required. Half course.

275-276—**Hydraulics** (75 with additional reading). Half course.

285-286—**Foundations,** including theory of earth pressure (85 with additional reading). Half course.

287-288—**Long Span Bridges.** Open to those who have taken Civil Engineering 87-88. Conferences, with reading and design work as required. Half course.

291-292—**Railroad Location:** advanced work in the Economics of Railroad Location, including a study of railroad operation with special reference to the application of the economic principles in the re-location of some existing railway or the location of a proposed road. Plans, Profiles and Estimates. Pre-requisite: Courses 89-90. Half course.

259-260—**Sanitary Engineering.** Pre-requisite: Courses 59, 94, 98. Full course.

277-278—**Hydraulic Engineering,** including the hydraulics of rivers and power plants and municipal water-works. Full course.

289-290—**The Engineering of Structures,** including long span bridges and deep foundations, with methods of building them, and advanced work in Elasticity and Resistance of materials. Full course.

293-294—**Railroad Engineering:** the design of the Permanent Way, including plans and specifications for roadbed, tunnels and culverts, track and track structures, yard and station layouts, block signals and interlocking. Pre-requisite: Courses 53-54, 58, 75, 85, 87-88, 89-90, and Mining 53. Full course.

DRAFTING

The drafting rooms and offices, situated on the fourth floor of the Engineering building, are equipped with a standard form of drafting table, and have a seating capacity for 175 students.

The collections of the department contain a complete set of models illustrating problems in projections and descriptive geometry, as well as the usual charts, blue prints, and models for use in the lecture and drafting rooms. A special feature of the collection is a full set of Olivier models illustrating the warped surfaces and problems in intersections and tangencies.

1, 2—Drafting. 1 hour and 14 hours drafting. Professors MAYER, MILLER and HARRINGTON, and Mr. BEANS.

(*a*) Elements of mechanical drafting—Use of instruments; plane problems; free hand lettering; dimensioning; (*b*) Projections—Orthographic projection; intersections; developments; problems in descriptive geometry; isometric projection; cabinet projection; (*c*) Machine drafting—Conventional signs for materials of construction; sketching of machine details. Working drawings; tracings; blue printing; (*d*) Topography—Conventional signs; hill shading; mapping.

3, 4—Descriptive Geometry. 3 hours. Professors MAYER, MILLER and HARRINGTON, and Mr. BEANS.

Problems on point, line, and plane; classification of surfaces; tangent planes to single curved surfaces and surfaces of revolutions; intersections; developments; warped surfaces.

5, 6—Drafting. 6 hours. Professors MAYER, MILLER and HARRINGTON.

(*a*) Graphics—Shades and shadows; perspective; (*b*) Stone cutting—Buttress; wing-wall; arches.

Pre-requisite: Drafting 1-2, 3-4.

7, 8—Drafting. 6 hours. Professors MAYER, MILLER and HARRINGTON.

(*a*) Structural drafting—Standard rolled sections; conventional riveting signs; standard connections; methods of framing and detailing structural work; beams; columns; plate girder; roof trusses; bridge details; (*b*) Machine drafting—Working drawings; tracing and blue prints of machine details; boiler and engine-room layouts, etc.

Pre-requisite: Drafting 1-2, 3-4.

ECONOMICS

2—3 hours. Professors SEAGER and AGGER and Dr. ANDERSON.

Introduction to Economics. Lectures, reading and text-book discussion. In this course the fundamental principles of economics are studied with particular reference to their application to current economic and social problems in the United States, and with special regard to the needs of students in engineering. Third-year students in Electrical and fourth-year students in Mechanical Engineering.

ELECTRICAL ENGINEERING

2—Elements of the Dynamo. 2 hours. Professors ARENDT and MORECROFT. (1 quiz period for E. E. students.)

A general consideration of the principles and parts of Dynamo Electric Machinery. History, definition of dynamo and motor, reversibility of functions, magnetic field, magneto-motive-force, hysteresis, elementary dynamo, generation of e.m.f., collector rings and commutator. Parts of the dynamo; the magnetic circuit, materials and function. The armature core: materials, eddy currents, forms, construction. The armature winding, material, function, multiplication of electro-motive-force, types. The commutator: materials and construction. Brushes: function, materials and supports. Field frame: materials, forms, development of magnetic flux, windings, magnetic leakage. Armature reaction: cause of, back and cross ampere turns, brush shifting, sparking at brushes and remedies. Action of different types of dynamos, and typical forms. Text-books: Crocker's *Electric Lighting*, Vol. I; Sheldon's *Dynamo-Electric Machinery*.

Pre-requisite: Physics 3-4 and 5.

4—Electric Distribution. 2 hours. Professor SLICHTER.

Principles and Methods of transmitting, distributing and controlling direct currents. Introductory, direct current series and parallel systems, feeders and mains, voltage regulation, networks, high tension d.c. systems.

Principles of alternating currents, self and mutual inductance, capacity, impedance, effective values of current and voltage, phase angle and power factor. Text-book: Crocker's *Electric Lighting*, Vol. II.

For E.M., C.E., Met.E., Chem.E. and San.E. students.

Pre-requisite: E.E. 2.

52—Design of Direct-Current Machinery. 2 hours and 1 afternoon. Professor ARENDT.

Application of electrical and mechanical theory to the design and calculation of D. C. machinery with complete and original designs of generators or motors in accordance with specifications, requiring all calculations and working drawings. Reference books: Thompson's *Design of Dynamos*, Cramp's *Continuous Current Machine Design*.

Pre-requisite: E.E. 2 and 101. Parallel course: E.E. 173-174.

54—Design of Alternating-Current Machinery. 2 hours and 1 afternoon. Professor SLICHTER.

The application of alternating current theory and practical data to the calculation and design of alternators, transformers, induction motors and other alternating current apparatus. Reference books: Arnold's *Wechselstromtechnik;* Thompson's *Dynamo Electric Machinery*, Vol. II, and McAllister's *Alternating Current Motors*.

Pre-requisite: E. E. 52, 103 and 105 and Mechanics 108. Parallel course: Mechanics 110 and E. E. 175-176.

72—Direct-Current Laboratory. 1 hour and 1 afternoon. Messrs. HEHRE, MASON and Assistants.

Short Course for students in Mining, Metallurgical, Civil, Sanitary and Chemical Engineering. The experiments cover the following: Fall of Potential, Resistance determinations, Study of various types of D. C. generators, their connections and characteristics of operation. Working of generators in parallel. Study of various types of motors, their connections, characteristics of operation and determination of commercial efficiency by brake tests. The results of these experiments are handed in as reports which are returned promptly to the students, with comments and corrections. Text-book: Morecroft and Hehre: *Short Course in Electrical Testing*.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2.

73—Direct-Current Laboratory Work. 1 afternoon. Mr. HEHRE.

Short course for students in Mechanical Engineering. Same as 72.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2 with parallel course E.E. 101.

75—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Messrs. HEHRE, MASON and Assistants.

Short course for Mining and Mechanical Engineering students. The experiments cover the following: Study of Elementary phenomena of alternating current circuits, with determination of inductance, capacity, impedance, true watts, apparent watts and power factor. Study of an Alternator, its operation, characteristic curves and wave form. Transformers: Their operation and commercial efficiency. Induction motors: Characteristics and efficiency by brake tests. Synchronous motors, their operation under various conditions and characteristic curves. Rotary converters, operation under various conditions of load and power factor (direct and inverted). Alternators in parallel, division of load and conditions for maximum economy. The student is required to prepare a report upon each experiment which is promptly corrected and returned to him for his instruction. Text-book: Morecroft and Hehre.—*Short Course in Electrical Testing.*

Pre-requisite: E. E. 72 or 73 and 4 or 104.

76—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Assistants.

Short course for Civil Engineers. Same as 75.

Pre-requisite: E.E. 4 or 104 and 72 or 73.

98—Thesis. Original investigation of and report on some problem of Electrical Engineering, approved of by the head of the department. Optional.

101—Generator and Motor Practice. 3 hours. Professor SLICHTER and Mr. HEHRE.

A course of lectures parallel to and descriptive of D. C. laboratory work. Short circuits and protective devices. Instruments: construction and use. Armature: e. m. f. current, resistance of, voltage drop in, windings and connections. Commutator: function, construction, heating, sparking, collecting brushes and holders. Magnetic circuit: calculation of flux and field windings. Heating of field and armature. Characteristics of the various types of generators and methods of regulation. Motors, theory of action and types. Methods of control and speed regulation. Losses and determination of efficiency by brake, stray power and pumping back methods. Text-books: Sheldon's *Dynamo-Electric Machinery.*

Pre-requisite: Phys. 5 and E. E. 2.

103—Electric Motors. 3 hours. Professor ARENDT.

(For E.E.) Electric motors, their action, control and application. Introductory. Classification of work requirements. Shunt Motors: Characteristics, predetermination of action, and efficiency, methods of speed control and regulation, rheostatic, field weakening, multiple voltage, double armature and teaser system. Series Motors: Connections, predetermination of characteristics and efficiency, control: rheostatic, field weakening, double armature and series parallel. Compound motor, characteristics and methods of control. Alternating current motors introductory. Commutator A. C. motors, series and repulsion types, characteristics and control. Synchronous Motors, characteristics and control. Induction Motors, single and polyphase, characteristics, methods of starting, speed control and regulation. Electric Drive, advantages of and application to machine tools, cranes, elevators, presses, pumps, fans, wood working and mill work. Text-book: *Electric Motors,* by Crocker and Arendt.

Pre-requisite: E. E. 104, 173 and 174. Parallel course: E. E. 175-176.

103A—Electric Motors. 2 hours. Professor ARENDT.

Electric Motors, their action, control and application. 103 abridged for Mechanical Engineering Students.

Pre-requisite: E.E. 104 and 73.

104—Electric Distribution. 3 hours. Professor ARENDT.

Principles and methods of transmitting, distributing and controlling direct and alternating currents. Introductory, Physical properties of conductors, direct-current series and parallel systems of distribution, feeders and mains, voltage regulation, three-wire systems, high voltage direct-current systems, network systems.

Principles of alternating currents, study of wave shapes, inductance, capacity, phase angle, effective values of electromotive force and current, power factor, resonance, simple circuits, parallel circuits, line inductance and distributed capacity, calculation of single phase circuits. Text-book: Crocker's *Electric Lighting*, Vol. II. For third year E. E. and M. E. students.

Pre-requisite: Phys. **5** and E.E. **2** and **101**.

105—Alternating-Current Engineering. 3 hours. Professor SLICHTER.

Electric power systems, including translating, controlling and transmitting equipments. Constant potential and constant current transformers, principles, efficiency, regulation and protection. Polyphase systems of generation, two phase and three phase, economy of generators, of transmission, and conversion from one system to another. Calculation of alternating current transmission lines, regulation of voltage and power factor of systems. Switch-boards, materials, apparatus used upon, location and types. Line construction and protection, pole lines, cable and conduit systems. Text-book: Steinmetz's *Electrical Engineering*.

Pre-requisite: E.E. **101** and **104**.

105A—Alternating-Current Engineering. 2 hours. Professor SLICHTER.

105 abridged for Mechanical Engineering students.

Pre-requisite: E. E. **101** and **104**.

106—Electric Plants. 2 hours. Professors SLICHTER and ARENDT and special lecturers.

Management of electric plants and industrial enterprises. Electric illumination, methods of charging for electric power, operating expenses, sources of income, organization and administration of corporations, reports, specifications, contracts, insurance regulations, patents and statistics.

Pre-requisite: E. E. **104** and **105**.

108—Plant Inspection. 3 hours. Professors SLICHTER and ARENDT.

Pre-requisite: E. E. **104, 173-174.** Parallel course: E. E. **105** and **106.**

109-110—Telegraphy and Telephony. 1 hour. Professor ARENDT.

The principal methods and instruments employed in telegraphy, telephony and electric signalling. Telegraphy: Historical review, Morse systems, relays and sounders, earth circuits, station equipments, repeaters, differential and polarized relays, duplex systems, quadruplex systems, telegraphy from moving bodies, recording systems, submarine cables and telegraph circuits. Wireless telegraphy: Generation of electrical waves, simple transmitting and receiving apparatus. Telephony: Historical review, Bell's work, the magneto-telephone, the microphone and carbon transmitters, use of induction coils, call methods, series and parallel circuits, subscriber's equipment, line disturbances, common battery systems, subscriber's and exchange equipment, party lines, automatic systems, combined telegraphy and telephony. Text-books: Maver's *American Telegraph Practice* and Miller's *American Telephone Practice.*

Pre-requisite: E. E. **104**.

112—Electric Railway. 2 hours. Professor SLICHTER.

Special instruction in calculation, installation and operation of electric railway systems. Historical review and early development. Train resistances due to tracks and bearing surfaces, curves, grades, and air. Acceleration and breaking. Speed time curves. Motors for railway work. Controllers. Distribution systems, track construction, bonding and electrolysis. Trucks, wheels and car bodies. Conduit, storage battery and third rail systems. Electric locomotives and multiple unit control. Testing railway equipments. Financial considerations.

Pre-requisite: For E. E. students E. E. **104** and **173-174**; for C. E. students E. E. **4** and **75**.

173-174—Direct Current Laboratory. 6 hours (2 afternoons). Mr. HEHRE and Assistants.

1. Practice in the accurate use of voltmeters and ammeters for the measurement of electromotive force and current. Determination of resistance of the electrical circuits of electrical machinery by "drop," comparison and direct deflection methods. Use of Wheatstone bridge for determination of high resistance. 2. Generators: Preliminary study to bring out relations between speed, field strength and voltage. Operation of shunt, series and compound-wound generators with determination of characteristic action of each type. Distribution of potential around commutator and distorting effects due to armature reaction. 3. Motors: Function and operation of starting boxes, study of motors, existence and measurement of c.e.m.f., operation of shunt, series, compound and differentially wound motors, determination of speed-load curves of each type. Efficiency tests by brake and prediction methods. 4. Operation of shunt and compound-wound generators in parallel, methods of connecting, distribution of load, effects of individual differences, etc. 5. Heat runs, to determine load capacity and efficiency of generators and motors by "pumping-back" tests. 6. Tests on constant current arc generators, series boosters, balancer sets, three-wire machines, series-parallel control of railway motors, etc.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2. Parallel course: E.E. 101.

175-176—Alternating-Current Laboratory. 1 hour lecture and 6 hours laboratory practice (one whole day) first term, 1 hour lecture and 6 hours laboratory practice (2 afternoons) second term. Professor MORECROFT.

1. Alternating current circuits; determination of inductance, capacity, impedance, phase relations, true and apparent watts and power factor. 2. Alternators; operation at different power factors, magnetization curves, determination of losses and synchronous impedance, field compounding, etc. 3. Alternators in Parallel: division of load, cross currents and adjustment of excitation for maximum economy. 4. Synchronous Motors: Methods of synchronizing, efficiency, action under varying conditions of load and field current. 5. Rotary converters: Methods of starting, operation direct and inverted, compounding, determination of voltage ratios regulating pole rotary and determination of efficiency. 6. Transformers: operation, determination of losses, regulation, heating and efficiency. Use as induction regulators and phase changers. 7. Wave Forms: determination of wave shapes and phase relations of electromotive-force and current in relative and non-relative circuits as well as in the primary and secondary circuits of transformers by instantaneous contact and oscillograph methods. 8. Resonance: by means of inductance and capacity in series, by inductance and leading current produced by synchronous motors, with application to transmission lines and rotary converter regulation. 9. Induction Motors: methods of starting, characteristic curves, determination of losses and efficiency by brake tests, application of circle diagram and use as frequency changer. 10. Induction Generator: operation and determination of the external characteristic. 11. Single-phase commutator motors, comparison of operation on a.c. and d.c. circuits; predetermination of characteristics by diagram. 12. Study of mercury arc rectifiers with curve analysis by ondograph and oscillograph. Text-book: Morecroft's *Laboratory Manual for Alternating Currents.*

Pre-requisite: E. E. 104 and 173-174. Parallel courses: E. E. 103 and 105; Mech. 109 and 110.

177—Instrument Laboratory. 1 hour and 2 afternoons. Mr. MASON.

1. Calibration of ammeters by comparison with laboratory standards. Kelvin balances, Siemens' dynamometers, and potentiometers. 2. Calibration of voltmeters. 3. Calibration, adjustment and determination of constants of A. C. and D. C. watt-hour meters, by various methods. 4. Determination of resistances: by Wheatstone bridge and potentiometer methods. 5. Measurements of Inductance and capacity. *a.* By comparison with standards using A. C. bridge. *b.* By absolute method, including determination of constants of ballistic galvanometer. 6. Magnetic measurements. Determination of coefficient of magnetic leakage of generator or motor. Determination of the permeability of samples of iron and steel. *a.* By Hopkinson's method. *b.* By Ewing double bridge method. *c.* A. C. voltmeter method. *d.* Direct reading voltmeter method. Determination of Hysteresis by Hopkinson's Double bridge. Voltmeter and Ewing tester methods. 7. Storage Battery Testing. Determination of normal rate of discharge, capacity and efficiency

at normal rates, capacity at various rates. Constant current and constant potential methods of charging, weight efficiency and losses on standing. 8. Photometry. *a.* Proving gas meters and determination of candle power of gas against standard candles. *b.* Candle power incandescent lamps using standard candle. *c.* Distribution of light from an incandescent lamp, using secondary standard. *d.* Determination of mean spherical and mean hemispherical candle power of an incandescent lamp. *e.* Relations between voltage, candle power, efficiency and life of incandescent lamps. Arc lamp photometry. 9. Cable Testing. *a.* To determine insulation resistance; induction and capacity. *b.* To determine location of faults.

Pre-requisite: E. E. 173-174.

Graduate Courses

101, 104 and 173-174—Dynamo and Motor Practice, Electrical Distribution and D. C. Electrical Laboratory. 3 hours lecture and 6 hours laboratory. Full course.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2.

175-176—Alternating-Current Laboratory. With Mechanics 109 and 110. 5 hours first half-year, 4 hours second half-year and 2 afternoons. Full course.

Pre-requisite: E. E. 104, 173-174, and Mechanics 108.

103, 105, 106, 175-176—Electric Motors, Alternating Current Engineering and Electric Plants, and Electrical Laboratory. 7 hours, 2 afternoons first half-year; 3 hours, 2 afternoons second half-year. Double course.

Pre-requisite: E. E. 104, 173-174.

GEOLOGY

4—Petrography. 2 afternoons two months of the second half, third year. Professor Berkey.

A short course in the microscopic study of rocks.

Pre-requisite: Mineralogy 6.

5-6—General Geology. 3 hours lectures, second year. Professors Kemp, Grabau and Berkey.

First half-year physical geology, with practical work in the rock collections under the lithological part of the subject; second half-year, stratigraphical and historical geology, involving laboratory work with index fossils and collections illustrating the geology of the United States. Text-books: Kemp's *Hand-book of Rocks;* Scott's *Introduction to Geology.*

Pre-requisite: Mineralogy 1-2.

15—Elementary Palæontology. Professor Grabau.

An introduction to the study of fossils. 1 hour lecture and 2 hours laboratory.

16—Index Fossils. 1 hour lecture, 6 hours laboratory, second term. Professor Grabau and Mr. Van Tuyl.

A study of the invertebrate fossils characteristic of the various geologic horizons of North America.

Pre-requisite: Geology 5-6.

18—General Geology. Professor Berkey.

A general discussion of dynamical, structural and historical geology, with practical work in the rock collections and assigned field work on Saturdays during the last six weeks. Special course during the second half-year for students in Civil Engineering only.

Pre-requisite: Mineralogy 5.

20—Rocks and Soils. 2 hours lectures and recitations, second term. Professor BERKEY.

A study of the residuary products from rock decay; types of soils; soil classification and mapping. Open to students who have completed a course in general geology.

Pre-requisite: Geology **18** or Geology **5-6**.

51—Principles of Geology. 2 lectures per week. Professors GRABAU and BERKEY.

Principles of the formation of sedimentary deposits, involving a discussion of marine and continental sedimentation, the criteria by which various sediments can be recognized, methods of preservation of organic remains, and the principles of geographic and geologic distribution of organisms. Principles of correlation. Text-book: Grabau's *Principles of Stratigraphy.*

Pre-requisite: Geology **5-6** or **18**.

52—Principles of Geology. 2 lectures per week, second term. Professors GRABAU and BERKEY.

A discussion of secondary structural features; and of formation of folds, faults, etc. Vulcanism, metamorphism, secondary mineralization.

Pre-requisite: Geology **5-6** or **18**.

101—Applied Petrography. 2 hours lectures and 1 afternoon laboratory work. Professor BERKEY.

Interpretation of rocks based on microscopic study. Rock origin, history, and present condition. Problems connected with ore deposits. Special course first half-year for students in Mining Engineering.

Pre-requisite: Geology 4.

102—Petrography of the Ores. Professor BERKEY.

This course is intended only for advanced students in petrography and economic geology. The chief object is to furnish a petrographic basis for the determination of the composition, structure and genesis of ores and ore deposits.

Pre-requisite: Geology **4**, **101**, **105** and **106**.

105-106—Economic Geology. 3 hours lectures and one elective conference, third year. Professor KEMP.

First half-year, discussion of the general features and formation of ore bodies, followed by a description of the deposits of the ores of iron, copper, lead, zinc, silver, gold, and the lesser metals, with especial reference to North America; second half-year, a description of the distribution and occurrences of coal, petroleum, natural gas, asphalt, building-stone, water supply, salines, and minor minerals. Text-book: Kemp's *Ore Deposits of the United States and Canada,* and lecture notes privately printed.

Pre-requisite: Geology **5-6**.

107-108—Invertebrate Palæontology. 2 hours lecture and 4 hours or more laboratory. Professor GRABAU and Mr. HINTZE.

First part of the course deals with the principles of palæontology; methods of study of the ontogeny of hard parts of animals, and the laws of morphogenesis. This is followed by a consideration of the classes of invertebrates important from a palæontologist's point of view, emphasis being laid on the features which show genetic relationship. Special attention is given to groups whose evolution has been worked out. Text-book: Zittel-Eastman, *Text-book of Palæontology,* Vol. I.

Pre-requisite: Antecedent work in Geology.

110—Geological Examinations and Surveys. 2 hours, second half fourth year. Professor KEMP.

A discussion of the methods of systematically recording and interpreting geological phenomena, with illustrations drawn from experience in mining and other branches of engineering: and of the organization and scope of geological surveys on a larger scale. This is followed by a sketch of the history and results of state and national geological surveys in this and other countries; and of other sources of detailed information regarding local geology.

Pre-requisite: Geology **105-106**.

112—Field Geology. All the officers of the Department.

A summer course of a week or ten days near New York for students in the course of Mining Engineering. Graduate students in the department may join the party. Instruction is given in the field in observing, recording, and interpreting geological phenomena and in the preparation of maps and sections. A written report is required.

Pre-requisite: Geology 5-6.

Geology 105-6 is desirable although not required.

201-202—Petrology. 2 hours lectures and 4 hours laboratory, fourth year. Professors KEMP and BERKEY.

A discussion of the origin, microscopic structure, and mineralogical composition of the crystalline rocks, and of metamorphism.

Pre-requisite: Geology 4.

205-206—Comparative Geology of North America. A comprehensive discussion of the geological formations and structure of the North American Continent. 3 hours lectures and 3 hours laboratory, with reading. Professors KEMP and GRABAU.

Pre-requisite: Geology 5-6 and 16.

LAW

Business Law. 2 hours. Mr. ROGERS.

A discussion of the elementary rules of law governing business transactions, including real property, contracts, agency, commercial paper, sales, suretyship, bailments, torts, partnership, corporations. The rules of law are developed and illustrated by examples taken from the law reports, and dealing with situations such as engineers have in fact met and are apt to meet in the practice of their profession.

MATHEMATICS

1—Algebra. 2 hours. Professors MITCHELL, GROVE and SICELOFF, Dr. REDDICK, Dr. LENNES and Mr. GRAVES.

Includes such topics as determinants, complex numbers, the theory of equations and partial fractions. First term.

Pre-requisite: Entrance Mathematics.

2—Algebra. Professor HAWKES and Mr. GRAVES.

Equivalent of 1. Second term.

3—Analytical Geometry. 3 hours. Professors MITCHELL, HAWKES, GROVE and SICELOFF, Dr. REDDICK and Mr. GRAVES.

Introduction to algebraic geometry, dealing with such topics as co-ordinate systems, transformations, loci and their equations, the straight line, circle, parabola, ellipse, hyperbola, and the geometric interpretation of the general equation of second degree. First term.

Pre-requisite: Entrance Mathematics.

4—Analytical Geometry. Professor GROVE.

Equivalent of 3. Second term.

64—Calculus. 5 hours. Professors FITE and GROVE, Dr. REDDICK, Dr. LENNES, Dr. FISHER and Mr. GRAVES.

An introduction constituting with 65 (see below) one course in the calculus. Differentiation of algebraic and transcendental functions, with applications to geometry, maxima and minima and mechanics. The elements of the integral calculus. Second term.

Pre-requisite: 3 (or 4).

65—Calculus. 5 hours. Professors FISKE, MACLAY, MITCHELL, FITE, Dr. REDDICK and Dr. LENNES.

Continuation of 64. Further study of the differential calculus; the principles of the integral calculus; applications to geometry, physics and mechanics. First term of second year.

Pre-requisite: 3 (or 4), and 64 (or 67).

67—Calculus. Professors GROVE and SICELOFF.

Equivalent of 64. First term.

68—Calculus. Professors GROVE and SICELOFF.

Equivalent of 65. Second term.

MECHANICAL ENGINEERING

11-12—Steam Power Machinery. 3 hours, with 1 afternoon in the second half year only. Professors LUCKE and PARR.

Functions, Forms and Principles of Operation of the Typical Steam power Plant Units, Auxiliaries and Connecting Elements—Methods of receiving, storing and firing coal, coal handling machinery, grates, stokers and furnaces for the combustion of coal; smokeless combustion and smoke ordinances; flow of gases through boilers, flues, dampers and the generation of necessary draft by chimneys, fans and steam jets. The construction and operation of boilers, boiler settings and foundations. Methods and apparatus for feeding water to boilers, necessary boiler attachments and trimmings. Flow of steam from boilers to engines and the grouping of engines and boilers, piping, valves, fittings and pipe covering. The heating of boiler feed water in feed water heaters and economizers. Purification of boiler feed water and effects of impure water on the boiler. Boiler strength tests and inspection laws. Boiler explosions. Steam pipe condensation and drainage. Steam traps, separators, steam superheating and superheaters. Condensing operation of steam engines by jet, surface, ejector and barometric condensers. Necessity for and types of circulating, hot-well and dry vacuum pumps and cooling towers. Typical steam engines and the variations in form and character of their important parts. Engine valves of simple and complete form, relation between construction of engine and valve gear to its economy. Special valve gears for high economy, for reserving and for power control. Regulation of engines and engine governors. Relation between engine construction, foundations, vibrations and balancing. Steam turbines. Typical steam plant arrangements for various special and standard conditions.

Second year mechanical and third year chemical engineering students.

Pre-requisite: Physics 3-4.

13-14—Steam Power Machinery. 3 hours. Professor LUCKE.

Short course adapted from M.E. 11-12. Second year Civil, Electrical and Sanitary; Third year Metallurgical and Mining Engineering.

Pre-requisite: Physics 3-4.

17-18—Engineering Thermodynamics. 2 hours. Professor LUCKE and Mr. THURSTON.

Laws of Heat Generation by Combustion, Heat Transfer and Transformation into Work—Relation between temperatures and quantities of heat. Units of heat. Effect of heat on solids, liquids, gases and vapors. Laws of heat transfer. Laws of surface evaporation, ebullition and condensation. Properties of saturated and superheated vapors. Combustion of fuels, calorific power, quantities of air for combustion. Temperature of combustion. Boiler efficiency and conditions affecting. Principles of chimney draft. Laws of expansion and compression of gases. Work and heat diagrams to pressure volumes and temperature entropy co-ordinates. Air and wet vapor compression. Expansion of steam by hypothetic, adiabatic and saturation laws and application to steam engine efficiency. Missing water in steam engines. Influence of cylinder condensation, re-evaporation, steam jackets, initial superheat, compounding and reheating on steam engine efficiency. Relation of boiler and engine performance. Free expansion laws and application to injector and steam turbine nozzles. Heat transformation by perfect gases. Hot air, gas and oil engine efficiency. Mechanical refrigeration. Effects of evaporation of

ammonia and carbonic acid and expansion of air. Heat balances and combined efficiency of complex systems.

Third year Mechanical, Electrical, Civil and fourth year Chemical Engineering; Fourth year Sanitary, first term only; Fourth year Mining Engineering and Met. E. for first term.

Pre-requisites: Mechanics 102; M. E. 11-12 or 13-14.

19-20—Engine Design. 3 hours and 2 afternoons. Professor RAUTENSTRAUCH.

Advanced Machine Design Based on the Thermal and Mechanical Problems Involved in the Design of a Steam Engine for Power, Economy and Regulation—Determination of ideal indicator card, probable M.E.P., piston speed, R.P.M., and displacement for required power, selection of single or multiple expansion construction from economy requirements, limits of clearance, cutoff, release, compression and admission for type of valve gear selected. Stresses due to steam and inertia in the principal parts. Forms and proportions of the parts determined by intensity, distribution and nature of the stresses, properties of the materials and conditions affecting maintenance. Determination of proportions of engine parts. Design of fly-wheels for limiting variation in velocity and analysis of resulting angular variation. Balancing the engine. Valve gears and governors, determination of the proportions of the valve for predetermined steam distribution, analysis of valve movements and moving gear. Graphic representation of the simultaneous events of valve opening, steam velocities and piston velocities. Analysis for the effect of the angularity of the rod. Equalizing the events of the valve. Analysis of the characteristics of the shifting eccentrics and the resultant variations in the valve events. Layout of the Corliss valve gear with single and double eccentric, and proportions of the mechanism. Steam engine governors, flyball and shaft governors, limits of movement, valve gear resistance. Proportions of the governor.

Fourth year Mechanical Engineering.

Pre-requisites: M. E. 39, 40, 11, 12, 17-18.

21—Gas Power Machinery. 4 hours and 1 afternoon. Professor LUCKE and Mr. THURSTON.

Theoretical and Practical Consideration Affecting the Generation of Power by Gas Engines, Including Oil Vaporization, Coal Gasification and the Design of the Machinery—Efficiency, M.E.P., displacement per minute per I.H.P. for reference diagrams. Limitations of external and internal heating. Methods of explosive and non-explosive internal heating. Properties of explosive gas mixtures, air necessary, calorific power per cu. ft. of mixture; temperature of combustion, heat suppression, efficiency of combustion, pressure and volume effects, limitations of proportions, temperature of ignition, rate of propagation, the explosive wave. Critical examination of modern gas engine forms and functions of parts; means for mixing and proportioning, pressure regulators, ignition; governors, effects on the engine and mechanism; starting equipment;exhaust piping and muffling; effects of back pressure in the engine; cooling; preignition, effect of cooling on economy. Large blast furnace practice, methods of gas cleaning; blast furnace gas, quality. Large engine construction, and forms of parts. Producer gas practice; standard producer for anthracite and bituminous coal, characteristics; gas, variation in quality, effects on the engine; methods of blasting producers, auxiliary steam supply and steam consumption; efficiency and rate of combustion in producer; scrubbers and tar extractors. Carburetors and vaporizers for liquid fuel; petroleum distillates, crude oil and denatured alcohol, vapor tension curves for liquid fuels. Characteristics of modern forms of gasoline and oil engines, gas power plant arrangements, producer engines, their efficiency, coal consumption and comparison with steam plants.

Complete analysis of the rating, efficiency, regulation, forces acting in and strength of parts of a modern gas engine. Probable indicator card, inertia of reciprocating parts, wrist pin and turning effort diagram. Dimensions of all parts.

Fourth year Mechanical Engineering.

Must parallel M. E. 19, 33.

25-26—Steam Power. 2 hours and 1 afternoon first term and 2 hours and 2 afternoons second term. Professor ———

Relation Between the Cost of Power and Thermal Efficiency of the Plant. Commercial Value of Refinements—Determination of engine and boiler ratings and corresponding efficiencies and probable coal and water consumption for plant on given load curve. Essential relation between processes and dimensions of the steam plant. Steam plant refinements for raising efficiency of part or complete plant and relations between dimensions and effect. Use of unit costs of apparatus in estimating, examination of cost sheets to determine prime unit of cost. Cost of power. Fixed and operating charges, ratio of each individual item to total and

effect of labor and fuel rates, load factor and refinements on the fractional part. Value of refinements of design on basis of capitalized annual saving by comparing the cost of waste and the cost of its elimination, including all charges. Specifications and contracts; standard and special methods and forms for defining purchaser's requirements and builder's proposals, contracts, methods of power plant erection. Designing and erecting office organization and field systems.

The work consists in laying out a simple power plant for assigned units in the drafting room or the detailing of existing general plant drawings, preparation of the bill of materials, estimating the first cost, fixed charges, probable coal, water, labor and supply cost for an assumed load curve and total power cost. The plants so designed or detailed are exchanged by students and redesigned for an increase of 100 per cent. peak and 50 per cent. mean daily load and for the maximum power cost reduction by the use of plant refinements and auxiliaries when it can be shown that additions and alterations will pay. Specifications are written for the alteration and proposals submitted.

Fourth year Mechanical Engineering.

Pre-requisite: M. E. 96S.

31-32—Standard Tests and Research Methods. 1 hour and 1 afternoon. Professor PARR.

Laboratory methods for the determination of experimental data. Derivation of physical laws from experimental results—Comparison of actual performance of machines with computed prediction and evaluation of unknown elements. Methods of approach for the solution of practical problems by experiment and computation. The work is illustrated by problems on the flow of liquids, gases and vapors, combustion, transfer of heat, steam generation and changes of state, transformation of energy, power generation and transmission, energy losses, thermal, hydraulic and mechanical. For each problem a preliminary report is submitted before the test, involving the analysis of the problem, the attempted prediction and the required test log, based on class-room explanations; this is incorporated with the tests results and an interpretation of differences between these and the prediction, including judgment of errors, to constitute the final report. The apparatus for this course includes: Pressure gauges, manometers, thermometers, pyrometers, indicators, tachometers, planimeters, barometers, weirs, channels, nozzles and orifices for water, steam and air, Pitot and Venturi tubes, steam, gas and water piping and meters, dynamometers, power scales, viscosimeters, flue gas apparatus, steam traps, hydraulic ram, steam injectors, air pump, hot air engine, duplex steam pumps, Pelton wheel, centrifugal pump, simple steam engine. Texts: *Experimental Engineering*—Carpenter & Diederichs, *Lecture Notes.*

Third year Mechanical Engineering.

Pre-requisites: M. E. 11-12. Courses which are parallel to it: M. E. 17-18

33—Standard Tests and Research Methods (Continuation of Course 31-32). 2 hours and 1 afternoon. Professor PARR.

The work of this course is the same in nature as 31-32, but the problems involve more difficult computations and more skilful manipulation of the apparatus. These problems are principally concerned with energy transformation, necessary and accidental losses and the determination of the conditions affecting performance of compound and triple expansion steam engines and pumps, operating condensing and non-condensing, with and without receivers, with and without reheaters. Hydraulic motors, one, two and three stage air compressors, with and without intercoolers, feed water heaters, fans, steam boilers, ammonia refrigerating machines, steam superheaters and condensers. Attention is also given to the commercial tests standardized by the Engineering Societies.

Fourth year Mechanical Engineering.

Pre-requisites: M. E. 31-32; M. E. 96S; M. E. 17-18.

35-36—Kinematics of Machinery. 1 afternoon. Professor THOMAS.

Determination of Paths of Motion, Velocity, Acceleration and Kinetic Forces of the Moving Parts of Machines with the Resulting Reaction Forces of the Frame—Relative motions of machine parts and the determination of the rates of motion. Determination of space, velocity and acceleration diagrams with application to the steam engine, shaper and other standard mechanisms. Construction and use of diagrams for the determination of inertia forces and their distribution in each element of a machine. The layout of motions to specifications. Design of cams with special reference to the rate of change of velocity of the moving parts and the resultant inertia forces, resistances to motion and the continuous contact of cam and follower. Analysis of link work, relative motions, inversions, adaptability to the accomplishment of specific kinds and limits of motion. Eccentrics and links

for the transformation of kinds of motion; ratchet motion; running ratchets. Clutch and coupling mechanisms, connecting shafts in parallel and at an angle. Modification to permit of non-alignment. Toothed gearings. Justification of the cycloidal and involute curves in their application to gear teeth. The layout of tooth forms and the determination of the velocity ratios. Layout of bevel gear tooth forms by Tredgold's method. Approximate methods and practical rules for the layout of gear teeth. Determination of paths of contact, obliquity of motion, length of teeth, interferences in involute gearing. Determination of the necessary conditions for interchangeability in sets of cycloidal and involute gears and comparison of the system. Friction gears. Kinematics of belt drive. Open and crossed belts. Layout of belt drives and rope drives, sprocket wheels and chain drives, speed, changing devices using wrapping connections. Text: Dunkerley's *Mechanism*.

Second year Mechanical and third year Electrical Engineering.

Pre-requisites are Math. 3-4 (35 must parallel 59, 59 Pre-requisite for 26, for M.E. students).

37—Machine Design. 1 hour, 2 afternoons, first half-year. Professor RAUTENSTRAUCH.

Adapted from M.E. 39-40.

Fourth year Chemical Engineers.

Pre-requisite: Drafting 7.

39-40—Machine Design. 3 hours, 1 afternoon, first half-year, 3 afternoons, second half year. Professor RAUTENSTRAUCH.

Analysis of stress in machine parts of standard form under varying conditions of service and the proportions of the machine elements to safely resist the resulting stresses—Application of the principles of Kinematics, Resistance of Materials, Design of Machine Elements, Shop and Foundry Methods to the design and analysis of complete machines. Examination of machines to determine the nature and distribution of the forces acting on and the resulting stresses and strains in each element due to kinetic and structural conditions. Selection of working stresses for machine parts subject to steady, repeated and reversed stresses. Selection of materials for machine parts based on their adaptability to the service and to the shop processes by which the part must be made. Determination of the proportions of machine parts subjected to tension, compression, and shear; bending and torsion; combined bending and tension, bending and torsion, torsion and compression, buckling action, and stresses due to eccentric loading and complex supports. Illustrated in the design of crank shafts, machine frames, housings and connecting rods. Gear wheels, pulleys, flywheels, springs, riveted joints, thin and thick cylinders, braces and stays, flat plate members, pressure joints, screws, belting, rope and chain drives for power transmission. Bearing surfaces, flat, cylindrical, pivot, ball, roller, thrust. Application of theory of elasticity to the more complicated elements. Grouping of machine elements into machines for functional operation, erection, adjustment, maintenance and repair and modifications demanded by facilities for manufacture. Design of machines to specification, with particular reference to modern requirements. Text: Spooner's *Machine Design*.

Third year Mechanical Engineers.

Pre-requisites: M. E. 35-36. Must parallel C. E. 53.

41—Machine Design. 1 hour and 1 afternoon. Professor THOMAS.

A short course adapted from M. E. 39-40.

Fourth year Civil and third year Electrical Engineering.

Pre-requisites: C.E. 53 for C.E. M.E. 35-36 for E.E. Must parallel C.E. 53 for E.E.

45-46—Hydraulic Turbines. 3 hours. Mr. HERRICK.

Description of operating conditions of water turbines—Principles of design and economy of operation of turbine wheels and water power plants—Action of water on curved vanes, forces developed and effect of impact, work done; centrifugal action. Theory of the turbine. Vane form and arrangement; total work done for axial, radial and mixed flow wheels; dependence of velocity of flow on speed of rotation; losses of energy due to friction in guide passages, wheel buckets and sluice, chock, leakage, residual velocity. Design of reaction turbines; relation between pressure and velocity of flow; methods of determining passage areas; radii of wheels, width and depth of buckets, number and thickness of vanes. Application of the theory of axial flow, parallel flow and mixed flow turbines. Tangential

impulse turbines; essential principles and theory, advantages, ventilation of bucket, velocity of flow, available energy, efficiency. Descriptions of and experiments with turbines of various types. Existing water power plants. Modern governors for turbines; ideal action of direct acting governor and disturbing influences; essential principle of indirect acting governor; factors affecting regulation. Selection and arrangement of water turbines and auxiliaries for different local conditions. Efficiency of turbines and plants. Text-books: *Water Power Engineering,* Mead; *Lecture Notes.*

Fourth year Mechanical Engineering (45) and fourth year Civil Engineering (46). Pre-requisites: For Mechanical Engineering: M.E. 36, M.E. 33, M.E. 60, C.E. 78; for Civil Engineers, M.E. 77, M.E. 78, C.E. 75, M.E. 63.

50 or 53—Steam Turbines. 3 hours. Professor ———

Fundamental Analysis of the Action of Steam Jets and Vanes and Its Application to the Design and Performance of Steam Turbines—Ratio of impulse to reactive force jets, effect of variation of curvature of the buckets, open and closed passages. Flow of steam through nozzles and turbine passages, volume, pressure, temperature, quality, weight, velocity and kinetic energy relations. Centrifugal effect of steam moving in a curved path. Study of the use of steam in varying types of turbines. Graded pressure turbines, graded velocity turbines, mixed impulse and reaction turbines. Practical turbines belonging to these types, and study of their detailed construction. Efficiency of different types studied by analysis of energy transformation throughout the path of steam and how efficiency is varied by design of blades, passages, nozzles, number of stages, speed, clearance, leakage and mode of regulation. Construction of turbine vanes. Disc and vane friction and critical speed. Governing steam turbines, throttling method, variable admission to one or more stages and periodic admission. Steam consumption of turbines. Book used: *The Steam Turbine*—Stodola.

Fourth year Mechanical (50) and Electrical Engineering (53).

Pre-requisites: For Mechanical Engineers, M. E. 17-18, M. E. 31-32; for Electrical Engineers, M. E. 17-18, M. E. 76.

52—Organization and Management. 3 hours. Professor Rautenstrauch.

Manufacturing Organizations and Methods of Cost Accounting—Effect of methods of manufacture and capacity on systems of management of mills and factories. Analysis of the elements of factory accounting and determination of the factors entering into the cost of production. Methods for keeping record of the cost of labor and materials in the production of specific articles. The determination of establishment charges. Interpretation of costs and use of comparative values. Determination of the depreciation of buildings, machinery, patterns, drawings and other assets. Organization and functions of the departments of the business. Purchase of raw material and sale of product. Utilization of scrap and waste. Methods of labor compensation. Critical analysis of the methods of accounting in representative factories. Factors affecting the cost of production. Layout of complete system of organization, forms and methods of accounting. Text-books: *Industrial Engineering,* Going; *Industrial Plants,* Day; *Factory Organization,* Diemer.

Fourth year Mechanical Engineering.

Pre-requisites: M.E. 94S, M.E. 54.

54—Shop Processes, Tools and Time Study. 2 hours. Mr. Halsey.

The Economic Elements in Shop Processes, Time and Power per Unit of Surface Finished or Cut and per Unit of Metal Removed with the Conditions for Most Economic Production—Processes in the shop, functional operation of machine tools and limits of economic production, time of setting, handling, forming and finishing of parts for job and repetition work in quantity. Limits of time, power and cost for finishing surfaces per sq. in. and removing per cu. in. and per lb. by hand and machine operations. Machines for performing specific operations, their functional operation, capacities, adaptability and rate of production. Conditions warranting jigs and fixtures for the production of parts in quantity and for interchangeability. Economy of portable tools, devices and methods of inspection. The selection of economic cutting conditions and analysis of recent experiments. Adaptation of economic cutting speeds to machine tools. Labor-saving devices in the pattern shop, tools and appliances used, capacity and adaptability; built-up patterns, single-piece patterns, metal patterns, comparative cost and life of each; patterns for repetition work, rights and lefts, a line of sizes, interchangeable patterns, jobbing patterns, relative economy of alternating practice. Economic production in the foundry, relative value of various methods of molding large and small parts, core making, venting, pouring and handling the work, managing the

cupola. Limits of labor, power and fuel per ton of castings as affected by size and form and fraction chargeable to pattern, molding and cupola and finishing. Processes of forging, hand and machine, conditions warranting power hammers, hydraulic presses, bull-dozers, presses, dies and forming devices for the production of duplicate and standard pieces. Labor and power per lb. of forging as affected by tools, size and form of work. Heating and annealing furnaces, consumption of gas and oil, labor, power and fuel per unit annealed. Distribution of cost of machine production between different processes, power, labor, material and effect of shop or tool capacity factor on fixed charges.

Third year Mechanical Engineering.

Pre-requisites are M.E. 94S, T. C. Shopwork and M.E. 39.

56—Hydraulic Turbine Installations. 1 hour. Mr. Herrick.

Selection and Arrangement of Water Wheels, Governors and Auxiliary Appliances for Different Local Conditions, Efficiency of Wheels and Plants—Characteristic of water flow through turbine guides, nozzles and buckets, conditions warranting wheel classification, efficiency of wheels as a function of type, head, speed and part gate operation, effects of different forms of gate on efficiency, relative value of standard patterns and special designs to suit local conditions, limits of standard dynamo speeds on wheel speeds. Water wheel governors regulation. Available head at wheels and division of total loss throughout water conductor system, relation between available water supply, possible output and perfection of development work; draft tubes, stop valves, gates, vacuum and pressure relief stand pipes, relief valves and bye-passes, water racks, anchor and frazil ice. Analysis of typical installations. Water power costs. Text: *Water Power Engineering*—Mead.

Fourth year Electrical Engineering.

Pre-requisites: C. E. 77. Parallel course: M. E. 60.

59—Empiric Design. 2 hours and 1 afternoon. Professor Thomas.

Proportioning of Machine Parts by Empiric Methods and the Production of Shop Drawings and Sketches—Modern practice in making, recording and filing shop drawings of machine details and assemblies, bills of material and listing of standard and special parts. Use of standard conventions and interpretation of shop notes on drawings. Shop sketches and dimensions. Forms of machine parts as indicated by the nature of the resistances to be overcome and the characteristics of the material. Plain, box, and ribbed cast sections, shrinkage stresses and the probability of local weaknesses. Proportions of parts by modern empirical formulas derived from practical considerations. Limiting conditions in the use of empirical formulas. Modern practice in the proportioning of machine elements. Proportions of parts adopted by the Master Car Builders' Association, Master Steam Boiler Makers' Association, United States Government, numerous manufacturing concerns and data appearing in the transactions of the various engineering societies and engineering publications. Design of simple castings from assigned data, dies for forming simple parts in a bull-dozer and the frames and parts of simple machines having given the detailed drawing of the other parts necessary to the determination of the principal dimensions.

Second year Mechanical Engineering and third year Chemical Engineering.

Pre-requisites: Drafting 1 or 2.

60—Hydraulic Laboratory. 1 hour and 1 afternoon for one-half term. Mr. Herrick.

Practical Work on the Flowing of Water for the Determination of Rational Coefficients with Ordinary and Extraordinary Conditions—Flow through simple holes in plate and short tubes under low heads. Flow through convergent nozzles and needle orifice. Flow through straight pipe, elbows and joints, distribution across the cross section near bends with velocity. Flow over weirs. Variation of rectangular, trapezoidal and triangular, sharp versus dull edge, approach contractions, one side, both sides and bottom. Hook gauge measurements. Measurement of quantity flowing by Venturi tube and Pitot tube. Variation of error with type, pressure drop, and size. Loss of heads by sudden enlargement in cross section in pipes running full. Inertia and water shock. Water wheels. Variation of efficiency with speed and head, analysis of losses in nozzles, bucket and friction. Efficiency of the Hydraulic Ram Test for reliability on commercial water meters. Text: *Lecture Notes.*

Fourth year Electrical Engineering and third year Mechanical Engineering, Met.E.

Parallel course: For Mechanical Engineering students, C. E. 78.

Pre-requisite for Electrical Engineering students: C. E. 77.

63—Hydraulic Laboratory. 1 afternoon. Mr. Herrick.

A more complete course based on M.E. 60. Fourth year Civil Engineering.

Parallel: Hydraulics, C. E. 75.

64—Air Machinery. 2 hours. Mr. LONGACRE.

Structures, Adaptability and Economy of Fans, Air, Gas and Vapor Compressors, Blowing Engines, Jet Blast Apparatus and Important Applications—Convection movement of air; flow of air through orifices, ducts, pipes. Hygrometric conditions of air with temperature and pressure and condensation of moisture in compressed air. Air compressors, types and construction; work of compression, M.E.P. for single and multi stage, cylinder ratios, effects of intercooling. Volumetric efficiency of compressors, real and apparent. Discharge pipe pressure pulsations, air receivers, intercooling receivers. Air end valves, poppet, slide, Corliss and ring valves, suction and delivery, differences in type and diameter and lift. Steam end valve gears and cylinder arrangement. Constant and variable speed compressor valve gear characteristics, pressure and speed controllers and governors. Analysis of complete compressor economy tests. Dry vacuum air pumps. Blowing engines, special forms and sizes of air end valves introduced by cylinders of large diameters for low pressure air. Ammonia and carbonic acid compressors; peculiarities and methods of handling liquid in the vapor; forms and characteristics. Multi-stage centrifugal fans and service. Analysis of efficiency tests for fans and blowers. Positive blowers. Steam jet blowers and exhausters, thermal efficiency. Application of principles to ventilation and heating, blast furnace practice, compressed air and compressed gas power transmission systems, air lift pumps and air brakes.

Third year Mechanical Engineering.
Pre-requisite: M. E. 17.

66—Elevators and Conveyors. 1 hour. Mr. MOSS.

Mechanical Handling of Solid Materials by Standard Elevating and Conveying Machinery, Characteristics, Speed, Tonnage and H.P. per Ton, Computations and Adaptability to Special Service—Hand handling of materials, limits, cost and conditions warranting use of machinery. Continuous conveyors, screw, bucket, scrapers, pusher, belt and pneumatic types. Intermittent conveyors; telephers, rope and cable ways, cable cars. Loaders, unloaders, storage facilities. Skips, grab buckets, tips and tipples. Short and long hoists, friction drum hoists and direct connected. Pneumatic and hydraulic elevators for freight. Fixed and travelling cranes. Passenger elevators, rope and plunger types. Safety devices. Automatic weighers of materials; coal and ore storage systems. Excavating machine and dredges. Coal and ore-handling machinery. Railroad terminal and steamship loaders and unloaders. Coke oven chargers and dischargers. Grain handling. Special adaptation to material, such as sand, plaster, glass, cement, broken rock, coal, coke, packages, barrels, corrosive, erosive, sticky, packing, and hot materials.

Third year Mechanical Engineering.
Pre-requisite: M. E. 39.

70—Pumping Machinery. 2 hours. Mr. NICKEL.

The Mechanics of Moving Liquids and Standard Machinery for Pumping—Water elevators, conditions for high efficiency and limits of use. Displacement, piston and plunger pumps; forms and functions of water pistons and plungers, pump bucket forms and limits of use, volumetric efficiency of water ends. Valves for water end, mechanical, flap, poppet, ball, annular, flat, double beat type and relation, adaptability to fluid, speed and temperature; forms of valve seats, conditions for perfect flow, piston speed and water inertia. Air chambers. Suction limitations of altitude, water temperature and absorbed gases and acceleration. Peculiarities of high pressure work, accumulators. Fly-wheel pumps, steam end characteristics, relation between steam and water diameters and displacements. Direct acting pumps, valve motion in single types, full and partial steam throw valves for simple, compound and triple use of steam. Duplex direct acting pumps, structural and operating characteristics. Economy of direct acting simple and multiple expansion pumps. Centrifugal and turbine pumps, forms and operative characteristics. High duty pumping engines, conditions for maximum duty referred to steam and coal; pumping engine tests, methods of conducting and analysis of results obtained. Typical pumping engine installations. Pulsometer pumps. Jet apparatus, injectors, ejectors and eductors, construction and duty as pumps. Water relief valves, pressure and float pump governors. Text: *Pumping Machinery*, Greene.

Third year Mechanical Engineering.
Pre-requisite: M. E. 17. Parallel C. E. 78.

72—Gas Power Machinery. 2 hours and 1 afternoon. Professor LUCKE and Mr. THURSTON.

Short course adapted from M. E. 22.
Fourth year Electrical and Metallurgical Engineering.
Pre-requisite: M. E. 17-18.

SCHERMERHORN HALL

74—Gas Power Machinery. 2 hours. Professor LUCKE.

Same as 72 except for the laboratory time.

Fourth year Mining Engineering.

Pre-requisite: M. E. 17-18.

76—Standard Tests. 1 hour and 1 afternoon. Professor PARR, Mr. HERRICK and Mr. WIESER.

Short course adapted from M. E. 31, 32, 33.

Fourth year Metallurgical, fourth year Chemical, fourth year Sanitary, and third year E. E.

Pre-requisite for E. E., Chemical and Metallurgical: M. E. 13-14 and M. E. 17.

77—Standard Tests. 1 hour and 1 afternoon. Professor PARR, Mr. HERRICK and Mr. WIESER.

Short course adapted from M. E. 31, 32, 33.

Third year Civil, fourth year Chemical and fourth year Electrical Engineering. Pre-requisite for Civil and Chemical Engineers: M. E. 13-14 and M. E. 17; for Electrical Engineers, M. E. 17-18.

78—Kinematics. 1 afternoon. Professor THOMAS.

Short course adopted from M. E. 36.

Third year Civil Engineering, Sanitary. Pre-requisite: Math. 3-4.

80—Experimental Mechanical Laboratory. 1 hour and 1 afternoon. Professor PARR.

Laboratory methods for the determination of experimental data and instruction in the operation of standard machinery. Standardization of pressure gauges, vacuum gauges, draft gauges, thermometers, pyrometers and steam engine indicators. Methods of measuring brake and indicated horsepower illustrated by the determination of mechanical efficiency of a steam engine. Correct methods for starting, stopping and operating steam engines, steam pumps, air compressors, fans and internal combustion engines. Valve setting on steam engines and direct acting pumps. Variation of steam consumption with load in a simple steam engine. Variation of horsepower to compress one thousand cubic feet of free air per minute with discharge air pressure. Variation of steam consumption of a direct acting pump with pumping head. Variation of gas engine and oil engine economy with load. Measurement of water flow by means of weirs, venturi meters, pitot tubes, orifices, recording water meters of various type and weighing tanks, and the determination of the limits of usefulness and accuracy of each method. Texts: *Power Plant Testing,* Moyer; *Lecture Notes.*

Third year Mining Engineering.

Pre-requisite: M. E. 13. Parallel course: M. E. 14.

82—Heating and Ventilation. 3 hours.

Principles of Heat Generation Transfer and Air Movement Applied to Warming and Ventilation of Buildings—Quantities of air needed for proper ventilation, amount of heat necessary to maintain temperatures against conduction, radiation and air change losses. Heating surface and coefficients of heat transfer, grate surface, pipe and duct sizes for high and low pressure steam heating, direct and indirect, hot water and hot air systems. Air tempering, cleaning, drying, humidifying. Pipe and duct layouts. Fan computations. Exhaust steam systems, vacuum circulation. Reducing valves, air valves, water expansion tanks, thermostats, thermostatic regulation systems and important details. Efficiencies of various systems and analysis of existing installations.

Fourth year Sanitary Engineering, M. E. 17.

94S—Shop and Factory Summer Work. Professor THOMAS.

Practical Work and Directed Study in the Shops and Drafting Rooms of Representative Manufacturing Establishments with Report—Each student is provided with a printed copy of the things to be studied and reported on in detail, of which the following is a general summary:

Machine Shop. Functional operation, characteristics and powering of machine tools, capacities, layout of shop, size of shafting, belting and motors for independent and group drive. Range of cutting speeds, feeds, depth of cut. Shape and

size of tools used. Report on specific observations on time of setting work, time of forming and finishing, number of pieces turned out per hour. Facilities for handling work at the machine. Facilities for producing pieces in quantity. Hand processes for finishing and tools used.

Pattern Shop. Materials of which patterns are made and methods of treating. Machine tools used in the pattern shop arrangement, capacities, adaptability, handing and storing of material and finished product.

Foundry and Forge, Description of hand and machine tools and appliances used in the foundry and forge. Compositing and treatment of foundry sands. Methods of molding. Time involved. Methods of powering, venting and chilling, cooling and finishing, handling the cupola. Composition of the charges and mixtures, temperatures, pressures, time required to charge, to melt, to pour, cool and clean. Appliances in the forge shop. Operation of power hammers, bull-dozers, shears, heating and annealing furnaces and hand processes of forging. Time involved in production.

Drafting Room. Standards and conventions used. Filing and marking of drawings and recording of patterns. Bills of material—parts to be made—standard parts in stock.

General Management and Organization. Methods of recording time of workmen and their time distribution over on different jobs. Paying of men, methods, rates, forms and records used. Drawing of materials used from storeroom and charging to orders.

Pre-requisite course is second year shop work.

96S—Steam Power Plant, Summer Work. Professor ———

Report based on not less than six weeks' practical work in an Operating Power Plant, including the Output, Load Conditions, Labor and Material for Operation and Maintenance, Operating Cost per Unit and the Essential Dimensional Relations between the Various Units and Auxiliaries Producing this Result—This work is done entirely by the student in the field, his only assistance being the blank report form which is put in his hands after a brief lecture on leaving the University for the vacation.

Third year Mechanical Engineering. Pre-requisite courses: **M. E. 17-18, 31-32.**

97—Mechanical Apparatus for Chemical Factories. 5 hours for 10 weeks in First Term. Professor Thomas.

Characteristics of the principal types of machinery and mechanical apparatus used by the manufacturers of chemical products, including the fundamental principles upon which their design is based, the method of operation, the selection and installation to meet given conditions of service, size and capacity of each unit, and economical arrangement of the plant. Pumping machinery; direct acting steam, simple, compound and triple expansion, belt and motor driven piston and plunger pumps. Centrifugal and turbine pumps; single and multi-stage, screw and rotary pumps. Jet apparatus; injectors, ejectors, steam and water jet blowers. Hydraulic presses; accumulators, heavy hydraulic apparatus. Air machinery: fans, blowers, positive blowers, turbo-compressors, piston compressors for single and multi-stage compression, intercoolers, regulating devices and unloaders. Hydraulic compressors. Blowing engines. Rotary and plunger types of vacuum pumps, air lift pumps. Refrigerating machinery; compression and absorption systems using ammonia. Dense air and carbonic acid machines. Ice making by can and plate systems. Compressors, condensers, stills, brine coolers and other units in refrigerating plants. Methods employed in the transportation of solid materials; elevating and conveying machinery, continuous and intermittent conveyors, loaders, unloaders, adaptability of system to material to be handled; hydraulic and pneumatic systems of transportation. Crushing and grinding machinery; methods employed for dry and wet processes, the handling of hard and soft materials; jaw, gyratory and roll crushers; roll, tube and ball mills for fine grinding, burr-stone mills. Separating and screening machinery; construction and operation of the types used in wet and dry processes; centrifugal and shaking screens, bolting reels. Mixing machinery for dry, plastic and wet material, mixing tanks, beating engines. Drying machinery; classification of apparatus for obtaining different degrees of dryness; construction and operation of suction apparatus, press rolls, steam driers for paper, kilns for cement, wood, pottery, by means of air currents. Humidifiers. Washing and boiling machinery; washing engines, digesters, kiers. Recording apparatus. Regulating apparatus for pressures and temperatures. Measuring apparatus for water, gas and steam, weighing machinery for solid materials. Pipe, pipe fittings, valves, conduits and ducts.

Precedes and forms sequence with Chemistry **197.** Fourth year students in Chemical Engineering. Pre-requisites: **M. E. 11** and **12, 17** and **18.**

Courses which may be Credited to the Degree of A.M. for Graduate Work Under the Faculty of Pure Science

Open only to students of Pure Science who have satisfied the pre-requisites.

117—**Engineering Thermodynamics.** 2 hours. Similar to M.E. 17, and subject to the same pre-requisites to entrance. One-half course. Professor LUCKE.

118—**Engineering Thermodynamics.** 2 hours. Similar to M.E. 18, and subject to the same pre-requisites to entrance. One-half course. Professor LUCKE.

119—**Engine Design.** 3 hours and 2 afternoons. Similar to M.E. 19, and subject to the same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH.

120—**Engine Design.** 3 hours and 2 afternoons. Similar to M.E. 20, and subject to the same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH.

121—**Gas-Power Machinery.** 4 hours and 1 afternoon. Similar to M.E. 21, and subject to the same pre-requisites to entrance. Double course. Professor LUCKE.

125—**Steam Power.** 2 hours and 1 afternoon. Similar to M.E. 25, and subject to the same pre-requisites to entrance. Double course. Professor ———

126—**Steam Power.** 2 hours and 2 afternoons. Similar to M.E. 26, and subject to same pre-requisites to entrance. Double course. Professor ———

131—**Mechanical Laboratory.** 1 hour and 1 afternoon. Similar to M.E. 31, and subject to same pre-requisites to entrance. One-half course. Professor PARR.

132—**Mechanical Laboratory.** 1 hour and 1 afternoon. Similar to M.E. 32, and subject to same pre-requisites to entrance. One-half course. Professor PARR.

133—**Mechanical Laboratory.** 2 hours and 1 afternoon. Similar to M.E. 33, and subject to same pre-requisites to entrance. Full course. Professor PARR.

145—**Water-Power Machinery.** 3 hours. Similar to M.E. 45, and subject to same pre-requisites to entrance. Full course. Mr. HERRICK.

160—**Hydraulic Laboratory.** 1 afternoon. Similar to M.E. 60, and subject to same pre-requisites to entrance. One-half course. Mr. HERRICK.

139—Machine Design. 1 hour and 1 afternoon. Similar to M.E. **39**, and subject to same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH.

140—Machine Design. 3 afternoons. Similar to M.E. **40**, and subject to same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH.

152—Organization and Management. 1 hour. Similar to M.E. **52**, and subject to same pre-requisites to entrance. One-half course. Professor RAUTENSTRAUCH.

166—Elevators and Conveyors. 1 hour. Similar to M.E. **66**, and subject to same pre-requisites to entrance. One-half course. Mr. MOSS.

170—Pumping Machinery. 2 hours. Similar to M.E. **70**, and subject to same pre-requisites to entrance. One-half course. Mr. NICKEL.

164—Air Machinery. 2 hours. Similar to M.E. **64**, and subject to same pre-requisites to entrance. One-half course. Mr. LONGACRE.

NOTE: Full course = 10 hours a week, including outside reading, preparation, etc. Double course = more than 10 hours a week.

METALLURGY

101—General Metallurgy. 3 hours first half of term. Professor KERN.

An introduction to general metallurgy; consideration of the methods. Object of the metallurgist, and application of physics and chemistry to the extraction, and to the treatment of the commoner metals. General classification of processes. Classification of fuels, and the selection of the most suitable fuels for certain purposes. The calorific value, and the temperature of combustion, of fuels. Preparation of charcoal and coke, and the recovery and utilization of their by-products. Artificial gaseous fuels, their preparation and metallurgical utilization. Properties of gases, and the metallurgical application of the laws of gases. Classification of furnaces, and the types of furnaces for specific purposes. Refractory materials, and their use in the construction of furnaces. Transmission of heat and the thermal efficiency of furnaces. Calculation of height, sectional areas, capacity and drafts of chimneys. Fuel economizers, and their application to metallurgical furnaces. High temperature measurements.

Third year students in Metallurgical Engineering. Fourth year students, Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Chemistry **3** or **4** and Physics **3-4-5**.

111—Metallurgy of Copper. 3 hours, second half of term. Professor KERN.

The production of copper, its uses, and consumption. Properties of copper and its alloys. The ores of copper, and distribution. Characteristics of ores of the principal districts. Sampling, and preparation of copper ores for treatment, and cost of different methods of sampling. General outline of the metallurgy of copper. Roasting of copper ores; purposes; chemistry; and methods of roasting. The advantages, disadvantages, and comparative cost of roasting processes. Introduction to smelting copper ores in reverberatory, and in blast furnaces. Composition, physical properties, and characteristics of furnace products; blister copper, black-copper, mattes, speiss, slag, and flue-dust. Smelting in reverberatory furnaces; construction of reverberatory smelting furnaces, their capacity and efficiency. Calculation of reverberatory furnace charges. Converting of copper matte in reverberatory furnaces. Smelting of copper ores in blast-furnaces. Calculation of blast-furnace charges. "Pyrite" or "Raw Ore" Smelting. Converting of copper

matte by the Malnés process. Apparatus required for converting copper matte. Refining of blister copper, black-copper, and cement-copper. Smelting of typical copper ores, producing ingot copper; the handling, and the disposition of the furnace products; cost of treatment.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 101.

118—Metallurgy of Copper. 1 hour. Professor KERN.

Advanced Course. Treatment of low-grade ores, and of copper-silver ores by leaching. Recovery of copper from mine-water. Utilization of furnace-gas for the production of sulphuric acid. Treatment of copper-nickel ores. Treatment of speiss. Metallurgical calculations of roasting and smelting operations. Application of thermo-chemistry to roasting, smelting and converting, and to calculations of furnace efficiencies. Purchasing of copper ores and fluxes.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111.

122—Metallurgy of Lead, Silver, Gold and Zinc. 3 hours. Professor WALKER.

Properties of lead, its compounds and alloys. Classification of ores. Production and uses of lead. Outline of the metallurgical treatment of lead ores. Smelting in the reverberatory furnaces; in the ore-hearth. Blast furnace practice for smelting lead ores. Roasting in hand and mechanical furnaces. Various pot-roasting processes and sintering machines. Smelting operations; construction of furnaces; calculation of charge; disposition, handling and treatment of by-products. Desilverization of lead bullion. Influence of impurities and elimination of same. Cupellation of rich lead alloys and ores. Treatment of Dore. Silver. Its properties, compounds, alloys, etc. Direct amalgamation of silver ores. Hydro-metallurgical processes for treatment of silver ores; Ziervogel, Patera, etc. Gold. Properties, etc. Amalgamation of gold ores. Chlorination processes. Cyaniding of gold ores; laboratory tests, and chemistry of the process; modern practice, description of existing plants. Refining and parting of gold and silver bullion. Zinc. Properties, ores, etc. Calcination and roasting of zinc ores. Retorting furnaces. Manufacture of retorts; retorting practice and chemistry of same. Refining of zinc.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 111.

128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. 1 hour. Professor WALKER.

Advanced Course. Methods of receiving and sampling different classes of ore. Purchasing of ore of varying compositions. General construction of furnaces, and design of smelting plants. Organization of smelting plants; metallurgical bookkeeping, cost sheets, etc.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 122.

131—Metallurgy of Iron and Steel. 1 hour. Professor WALKER.

Manufacture of iron and steel. Blast furnace. Puddling. Cementation. Crucible process. Bessemer process. Open hearth process. Statistics. Iron and steel casting. Effect of heat treatment. Effect of mechanical treatment. Malleable cast iron. Standard specifications. Constitution of iron and steel. Relation to physical properties. Change of structure with heat and mechanical treatment. Alloy steels. Corrosion.

Fourth year students in Mining, Metallurgical, Chemical Engineering, and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4-5. Pre-requisite or parallel: Metallurgy 101.

134—Metallurgy of Iron and Steel. 2 hours. Professors WALKER and CAMPBELL.

Introduction, literature, scheme of iron and steel manufacture. Definitions: iron, steel, cast iron, etc. Relations of carbon and iron. Development of the industry. The blast furnace, iron ores, fuels, fluxes, smelting practice, products. Processes for purification of pig iron. Manufacture of wrought iron and crucible steel. Puddling, charcoal hearths, fineries. Cementation, blister steel. Crucible process. Bessemer process, acid and basic. Siemens-Martin or Open Hearth process, acid and basic; fuels and regeneration. Defects in ingots and other

castings. Iron and steel founding. Mechanical treatment of steel, forging, rolling. Heat treatment of steel. Heat treatment of cast iron. Malleable cast iron, cupola and air furnace. Alloy steels; nickel; vanadium; manganese; chrome; tungsten, etc. Self-hardening, high-speed steels.

Practical metallography of iron and steel. Macroscopic examination. Microscopic examination of wrought iron, pipe steel, low carbon and structural steel. Shafting, etc. Medium and high carbon, rails and tires. Tool steels. Cast irons. Comparison of good with bad material. Relation between structure and properties. Corrosion. Standard specifications. Electrometallurgy of iron and steel.

Second year students in Civil, Electrical, and Mechanical Engineering. Pre-requisite: Chemistry 3 or 4 and Physics 3-4-5.

138—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Advanced Course. A detailed study of the constitution of iron and steel and the effects of heat and mechanical treatment upon the constituents. Discussion of the various processes of manufacture of iron and steel, alloys steels, etc. The iron and steel industry of the United States, Germany, England, and other countries. Standard methods of testing.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 131.

141—Electrometallurgy. 1 hour. Professor KERN.

Theory of the electric current, and its application in the treatment of ores, refining of metals, and production of refractory alloys. Theory of electrolysis; determination of efficiency. The solution pressure series of the metals, and its application in the refining of copper, lead, iron, nickel, antimony, tin, zinc, gold, and silver. Electrolytic refining of copper. Electrolytic refining of lead. Treatment of anode residual. Parting of silver and gold by electrolysis. Refining of gold alloys. Electrolysis of fused electrolytes; production of aluminum; treatment of sulphide ores, etc. Electric furnaces used: for smelting ores, for refining metals, and for manufacture of refractory alloys. Efficiency of electric furnaces; cost of constructing and maintaining.

Fourth year students in Mining and Metallurgical Engineering, and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4-5.

148—Electrometallurgy. 1 hour conference. Professor KERN.

Advanced Course. Construction of electrolytic refineries; calculations of current, and power efficiencies. Selection of most suitable electrolyte, and most economical current density. Labor-saving appliances. Electrolytic deposition of copper, lead, zinc, nickel, gold and silver from solutions obtained by leaching their ores. Production of solid deposits, and laws governing the same. Rôle of current density in the electrolysis of aqueous and fused electrolytes, and in the operation of electric furnaces. Application of thermochemical calculations to electrolytic, electro-thermic, and electric furnace operations. Calculation of efficiencies of electric furnaces and of electro-thermic operations.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 141.

151—Constitution and Properties of Alloys. 2 hours. Professor CAMPBELL.

Pyrometry and freezing point or cooling curves. Various types of curves and their meaning. Examples of the same. Constitution of the various binary alloys. Methods of manufacture of commercial alloys. Ternary alloys. The phase rule. Change of structure in the solid state, pure metals, alloys, bronze, brass, steel. Methods of metallographic research.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111; Parallel Metallurgy 131.

155-6—Metallography. Iron, Steel and Industrial Alloys. Six lectures and 3 or more afternoons laboratory. Professor CAMPBELL.

Methods of examination. Comparison of good and bad material; wrought iron, low carbon steel, structural steel, rail steel, tool steel, etc. Examination of brasses, bronzes, bearing metals and other industrial alloys. Relation between chemical composition, physical properties and microstructure.

Course for students in Mechanical Engineering, and for special students. Pre-requisite: Metallurgy 131 or 134.

158—Advanced Course on Constitution and Property of Alloys. 1 hour. Professor CAMPBELL.

Fourth year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 151.

62S—Summer Course in Non-Ferrous Metallurgy. Professor KERN.

For description see page 37. 1 week field work at metallurgical plants during the summer.

Instruction for this field work will be given in five one-hour conferences during the last week in April.

Third year students in Mining Engineering.

64S—Summer Course in Ferrous Metallurgy. Professor CAMPBELL.

For description see page 37. Third year students in Metallurgical Engineering.
Pre-requisite: Metallurgy **101**.

66S—Summer Course in Non-Ferrous Metallurgy. Professors WALKER and KERN.

For description see page 37. Third year students in Metallurgical Engineering.
Pre-requisite: Metallurgy **122**.

72—Metallurgical Laboratory. 10 consecutive afternoons, second term. Professor CAMPBELL and Professor KERN.

Calibration of Le Chatelier pyrometer. Cyaniding and chlorination of gold ores. Roasting of copper matte, and use of pyrometer. Desilverizing of base bullion by Parke's process. Microscopic metallography. Thermal treatment of steels.

Fourth year students in Mining Engineering.
Pre-requisite: Metallurgy **111**. Parallel: Metallurgy **122**.

171—Metallurgical Laboratory. 3 afternoons. Professors WALKER, CAMPBELL and KERN.

Calibration and comparison of thermo-electric, optical and radiation pyrometers. Determination of the calorific power of fuels by the Mahler-Berthelot calorimeter. Microscopic study of metals and alloys. Thermal and mechanical treatment of steels. Roasting of copper matte, and use of pyrometer. Production of blister copper by the reaction process. Refining of blister copper. Desilverization of base bullion by Parke's process. Cyaniding of gold and silver ores. Chlorination of gold ores. Electrolytic refining of copper and lead bullion. Fusibility of slags and refractory materials.

Fourth year students in Metallurgical Engineering. Parallel: Metallurgy **101** and **111**.

172—Metallurgical Laboratory. 2 afternoons. Professors WALKER, CAMPBELL and KERN.

Special investigation in some subject or subjects in either ferrous or non-ferrous metallurgy. Subjects are similar to those noted under the head of Met. 201-202.

Fourth year students in Metallurgical Engineering.
Pre-requisite: Metallurgy **171**.

173-174—Metallurgical Laboratory.

Special work along the lines indicated under the head of Metallurgy 201-202. This work is intermediate between that of Metallurgy **171** and **201-202** and is designed for those desiring to take an advanced metallurgical laboratory course without confining themselves to special research work.

Pre-requisite: Metallurgy **171**.

175—Metallurgical Investigation. 1 hour conferences. Professors WALKER and CAMPBELL.

Fourth year Metallurgical Engineers. Pre-requisite: Metallurgy **122**. Pre-requisite or parallel: **131**, **141**.

77—Metallurgical Plant Construction. Professor WALKER.

General design of metallurgical plants and problems entering into the construction of same.

Special work is assigned to each student, which is carried on under direct and constant supervision in the drafting room and laboratories. The experience gained in visits to metallurgical plants is brought into practical use.

Fourth year Metallurgical Engineers. Pre-requisite: Drafting **3-4**, **7-8**; Civil Engineering **53**; Metallurgy **122**, **64S** and **66S**.

81—Assaying. 2 hours, 3 afternoons. Professor HALL.

Ores and metallurgical products. Text-books: Fulton's *Manual of Assaying*. The assays included in this course are: Preliminary (reagents, etc.): lead ores; gold and silver ores; pure and impure, including galena, stibnite, arsenopyrite, blende, pyrite, tellurides, etc.; mattes and tailings; corrected assays and cyanide solutions; gold, silver and lead bullions.

Third year students in Mining Engineering and Metallurgical Engineering.
Pre-requisites: Chemistry 3 or 4 and 61 or 62; Mineralogy 1-2 or 7-8.

82S—Summer School in Assaying. Professor HALL.

182—Assaying. 2 lectures or recitations. 2 afternoons. Professor HALL.

A short course covering practically the same ground as Met. 81.
Third year students in Chemical Engineering and Chemistry.
Pre-requisites: Chemistry 3 or 4 and 61 or 62; Mineralogy 1-2 or 7-8.

188—Assaying. Advanced course. Professor HALL.

For those desiring to take special work in assaying.
Pre-requisite: Metallurgy 81 or 182.

Graduate Courses

Special courses, consisting of original research, will be arranged for graduate students according to their individual needs and abilities. Most of these researches will consist of work in the departmental laboratories, but others will consist of study, and still others of work in industrial establishments.

The following list shows what subjects are suited to these courses:

201-202 (*a*)—Advanced work on some problem in general metallurgy, as for example:

In Calorimetry: Determination of the calorific power of fuels, or testing some law in calorimetry;

In Pyrometry: Determination of the temperatures of metallurgical and other industrial high-temperature operations;

On Refractory Materials: Their resistance to heat and corrosion; their tendency to slack; their contraction and expansion, etc.;

On Slags: The formation points, melting points, flowing points, and their density and viscosity when molten;

(*b*)—In the Metallurgy of Copper:

The chemistry of roasting processes, such as the elimination of arsenic and sulphur; chloridizing and sulphate roasting, etc.

The reactions of smelting processes;

Wet methods of extraction;

(*c*)—In the Metallurgy of Lead, Silver, Gold, etc.:

The pot-roasting of sulphides, and others mentioned above under (*b*);

(*d*)—In the Metallurgy of Iron and Steel:

The effect of various constituents on Iron and Steel.

The heat and mechanical treatment of Iron and Steel; effect on physical properties and microstructure.

The study of alloy steels and the effect of heat treatment. Case hardening, etc.

(*e*)—In Electro-metallurgy: Testing electro-metallurgical principles, refining, extraction and depositing process;

(*f*)—On Alloys: The constitution and properties of alloys, embracing a microscopic, pyrometric and mechanical or physical examination with a correlation of the results;

(*g*)—In Metallography: Metallography of iron, steel, industrial alloys or metallurgical products, as mattes, slags, etc.

Pre-requisite for 201-202: Metallurgy 122, 131, 141 and 171, or equivalent.

MINERALOGY

1-2—Descriptive and Determinative Mineralogy. 3 hours lectures throughout the year, 6 hours laboratory first term, 3 hours laboratory second term. Professors Moses, Luquer and Assistants.

The elements of crystallography. The blowpipe analysis of ores and other substances. The study of the important minerals, the purpose being: 1st. Sight recognition of average specimens of all common or economically important species; 2d. Rapid determination of the less characteristic specimens by simple tests; 3d. Familiarity with economic characters.

Pre-requisite: Entrance requirements in Chemistry and Physics. Prescribed course for students in Mining.

5—The Minerals of Building Stones. 2 hours lectures and 1 afternoon laboratory. Professor Luquer and Assistant.

Study of common species, their properties, methods of determination, and their economic effect on building stones.

Pre-requisite: Entrance Chemistry and Physics. Prescribed for students in the course of Civil Engineering.

6—Optical Mineralogy. In sections, 2 afternoons per week for first seven weeks of term. Professor Luquer and Assistant.

Principles, apparatus, and distinguishing characters of minerals in thin sections. Consists principally in the determination of minerals in rock sections by the aid of the polarizing microscope. Supplements Courses 5, 1-2 and 7-8 and is preliminary to Geology 4 (petrography).

Pre-requisite: Course 5, or part of Course 1-2, or 7-8, or the equivalent. Prescribed for students in Mining and Metallurgy.

7-8—Descriptive and Determinative Mineralogy. 3 hours lectures, 3 hours laboratory. Professors Moses, Luquer and Assistants.

Modification of Mineralogy 1-2. Lectures identical, laboratory work condensed. Prescribed course for students in Metallurgy.

Prerequisite: Entrance Chemistry and Physics.

10—Mineralogy and Crystallography. 2 hours lectures and 3 hours laboratory. Professor Moses.

Supplements Mineralogy 15-16 by first, further instruction in sight recognition of increased number of species; second, crystal measurement and determination of constants; third, the study and determination of minerals and crystals with the polarizing microscope.

Pre-requisite: Mineralogy 15-16. Prescribed for third-year students in Chemistry.

15-16—Determinative Mineralogy. 3 hours laboratory. Professor Moses and Assistant.

Sight recognition and determination of minerals important in the chemical industries.

Pre-requisite: Entrance Chemistry and Entrance Physics. Prescribed for students in Chemistry and Chemical Engineering.

MINING

Undergraduate Courses

51—Excavation and Tunneling. 3 hours, third year. Professor PEELE.

Excavation of earth: tools and methods employed, support of excavations, special methods for quicksand and other water-bearing material; steam shovels and other mechanical excavators; handling and transportation of excavated material; comparative costs. Explosives: black powder, nitro-glycerine and its compounds, and other high explosives; their composition, manufacture, and use. Excavation of rock: methods of drilling and blasting mammoth blasts, submarine blastings. Railroad tunnels: methods of driving and timbering; handling and transportation of excavated material; drainage and ventilation; lining of tunnels, subaqueous tunnels. Mine tunnels; examples from practice; sizes, details of driving, timbering, rates of advance and costs.

Required of students in the course of Mining Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry, and Physics.

52—Boring and Shaft Sinking. 2 hours, third year. Professor PEELE.

Boring: methods and appliances for small depths and for deep boring; rod boring and oil-well or churn drill method; boring with core drills, for prospecting and other purposes; survey of bore-holes. Shaft sinking: methods and tools employed in rock and in soft material, sinking linings or drop-shafts, freezing and other special methods of sinking in soft water-bearing formations; drainage of shafts; handling and hoisting of excavated material. Shaft timbering, walling, tubbing, and other forms of lining. Costs of shaft sinking.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51.

53—Excavation, Tunneling, Boring and Shaft Sinking. 2 hours, second year. Mr. JUDD.

A condensation of courses 51 and 52, in which attention is given only to those operations that are of special interest to the civil engineer. Excavation and transport of earth for structural purposes and railroad grading; steam shovels and dredges. Explosives. Excavation of rock; methods of drilling and blasting; submarine blasting; railroad tunnels; quarrying; testing for foundations in earth, rock and watery material; well drilling; shaft sinking by usual and special methods.

Required of students in the course of Civil Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry and Physics.

54—Exploration, Development, and Methods of Working. 3 hours, third year. Professor MUNROE.

Mineral deposits, characteristics of beds, masses, veins, and other deposits, and the irregularities and disturbances to which they are subject, as affecting the work of exploration and mining. Examination and survey of mineral properties; relation of topography to geological structure; construction of maps and sections; and tracing of probable outcrops as a guide to exploration. Prospecting by ditches, pits, and deep boring. Development; choice of methods; location of openings. Working of deposits and support of excavations; theoretical considerations, methods of breaking ground in coal and metal mining, and support of mine excavations by pillars of mineral, by timbering, by masonry, and by rock filling; methods of working applicable to deposits of different thickness, inclination, and character. Coal mining; vein mining; working of thick deposits and soft-ore bodies. Salt mining. Surface working. Hydraulic mining and gold dredging.

Required of students in the courses of Mining and Metallurgical Engineering. Pre-requisite: Geology 5-6. Pre-requisites or parallels: Geology 105-106, Mining 51 and 52. Accepted together with Mining 81 and 82, or with Mining 56 and 91, as a minor for the degree of A.M.

56—Mine Engineering. 3 hours, fourth year. Professor MUNROE.

Ventilation; air of mines; mine gases; methods of ventilation; control and measurement of air currents. Drainage: sources of mine waters; methods for the control and raising of water; dams; drainage levels. Water supply. Surface handling and transportation; arrangements for loading and unloading cars and vessels, and for storing of minerals. Mineral railroads. Common roads. Acci-

dents to men in shafts, levels and working places; fire-damp and dust explosions; mine fires; inundations; rescue and relief of men. Mine surveying, mine maps and models. Examination, sampling and valuation of mines.

Required of students in the course of Mining Engineering. Pre-requisites or parallels: Mining 54 and 71-72, Civil Engineering 76 and 28. Accepted together with Mining 54 and 91, as a minor for the degree of A.M.

71-72—Mine Plant. 3 hours, fourth year. Professor PEELE.

Description and critical discussion of the machinery and appliances employed in the equipment of mines; design, erection and care of plant. Hoisting: engines, drums, wire rope, skips and cages, head-frames; calculation of power required and methods of equalizing the load on the engine; shaft-sinking plant, over-winding. Drainage: buckets, tanks and hand-pumps; Cornish and direct-acting underground pumps; operation of pumps by electricity, compressed air, and hydraulic power. Centrifugal pumps. Ventilation: underground furnaces, positive blowers, and centrifugal fans; theory and efficiencies of fans. Air compressors: simple and compound (stage) compression; methods of dealing with heat of compression; conveyance of compressed air in pipes; reheating; operation of machinery by compressed air; efficiencies. Machine drills; coal-mining machines or coal-cutters. Handling mineral in working places. Mine cars; arrangement and construction of tracks. Underground haulage; hand tramming; mule haulage; gravity roads; steam, compressed-air, and electric locomotives; rope haulage; efficiencies; comparison of systems of haulage.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51, 52 and 54, and Mechanical Engineering 13-14. Accepted together with Mining 73 and 75, as a minor for the degree of A.M.

73—Mine Constructions. 1 hour, fourth year. Professor PEELE.

Building-stones; bricks; limes; cements and concretes. Foundations in various soils; retaining walls; masonry and timber construction, with special reference to mine work; mine buildings; trestles; ore-bins.

Required of students in the courses of Mining and Metallurgical Engineering. Accepted together with Mining 71-72 and 75, or with Mining 81, 82 and 75, as a minor for the degree of A.M.

75—Design of Mine Plant. 4 afternoons, fourth year. Professors PEELE and KURTZ and Mr. JUDD.

The students are assigned problems in the design and construction of mine plant, in connection with the development of a mine. This work supplements the lectures on the design of mining machinery, involving reading and study, and the preparation of working drawings, covering certain portions of the plant, together with bills of material, specifications, and estimates. As these drawings are intended to accompany and illustrate in part the graduating theses or projects, the designs are made in accordance with the subjects and conditions therein assigned. The work is done under constant supervision and advice in the draughting-room.

Required of students in the course of Mining Engineering. Pre-requisite: Drafting 3-4, 7-8, Civil Engineering 53, Mining 59. Parallel: Mining 71-72. Accepted together with Mining 71-72 and 73, or with Mining 81, 82 and 73, as a minor for the degree of A.M.

77-78—Graduating Thesis or Project. Professor PEELE.

Mining Thesis

The subjects for the graduation theses are assigned during the third year, and are made a part of the regular course of instruction. The subject given in each case is the problem of the opening and development of a mine, supposed to be located in some well-known mining district, and for which certain definite conditions as to size and character of ore body, amount of water to be pumped, and quantity of ore to be mined, are assumed. During the summer field work in mining the student incidentally obtains data for his thesis work. This information is supplemented by study of books and technical literature. During the fourth year he decides upon the proper methods for opening, developing, and working the property; and makes estimates of the plant, machinery and capital required, the cost of working, and the probable profits. He also works out in detail certain portions of the proposed mine plant, and prepares a set of working drawings, bills of materials and specifications therefor. This work, done under the supervision of competent instructors, constitutes both a review and a series of practical applications of the preparatory studies and enables the students to discover and remedy their deficiencies, giving them confidence in their ability to work out similar problems later.

Required of students in the course of Mining Engineering. Pre-requisites or parallel: All the required courses in Mining.

80—Mill Constructions. 1 hour, fourth year. Professor KURTZ.

Installation and operation of mechanical power transmission and auxiliary machinery in works for the mechanical treatment of minerals. Dealing with shafting, bearings, pulleys, belting, rope drives, gearing, etc.

Pre-requisite: Mechanical Engineering 13-14.

81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. 4 hours, fourth year. Professor MUNROE.

The general principles and theory of dressing; preliminary operations; hand dressing; cleansing; crushing; jigging with and without preliminary sizing; slime concentration; magnetic and electro-static separation; oil and flotation processes; milling of gold ores; descriptions of typical dressing works and coal-washing plants in this country and abroad.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mineralogy 1-2, Physics 3-4, and Mechanics 102. Accepted together with Mining 54 and 82, or with Mining 82, 73 and 75 as a minor for the degree of A.M.

82—Ore-dressing Laboratory. Afternoon work for three weeks, fourth year. Professors MUNROE and KURTZ and Mr. JUDD.

Mechanical testing of ores by laboratory methods; working tests with simple apparatus; adjustment and operation of concentrating machines.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mining 81. Accepted together with Mining 54 and 81, or with Mining 81, 73 and 75, as a minor for the degree of A.M.

91—Mine Administration. 2 hours, fourth year. Professors MUNROE and KURTZ.

Administration, organization, and business management, mine accounts, and cost sheets.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mining 54. Accepted together with Mining 54 and 56, as a minor for the degree of A.M.

94—Mining Law. 2 hours, fourth year. Professor KURTZ.

General principles of real estate law. Historical review of mining laws of different countries. Federal laws, concerning locations on public lands of the United States. State and territorial mining laws.

Pre-requisite: Civil Engineering 27, Mining 54.

Summer Courses

58—Summer Class in Mine Surveying is held in June, at a mine in a near locality, and lasts one week. Professors MUNROE and KURTZ and Mr. JUDD.

Pre-requisite: Civil Engineering 27.

59—The Summer Courses in Practical Mining. Professors PEELE and KURTZ and Mr. JUDD.

Held in June and July, at some mine or mines selected for the purpose, in the vacation between the third and fourth years, and lasts six weeks (for details see page 33).

Pre-requisite: Mining 51, 52 and 54, Civil Engineering 15 and 27, Mechanical Engineering 13-14, and Geology 105-106.

Graduate Courses

Special courses, consisting of personal instruction, reading and experimental investigation, will be arranged for advanced students according to their individual needs and ability. These investigations will be made at mines and dressing works either in connection with the Summer class or elsewhere as assigned, with additional work, as required, in the library and in the laboratories of the department. The time required is governed by the rule that a full course should occupy

10 hours (outside reading and study included) per week for a half year. Any of the following may be offered for the degree of A.M. by students who have had the appropriate pre-requisites:

101-102—Mining and Ore Dressing. Mining 54, 81 and 82, with laboratory work and reading as required. Two full courses.

Under the regulations for the degrees of A.M. and Ph.D. the following courses may be offered by graduate students who have had all the undergraduate courses in mining or their equivalent.

201-202—Methods of Mining. Critical study of methods used in some mining region, or for a certain class of deposits; output per man, amount of timber and explosive required, and other details affecting cost. Study of conditions as determining choice of method. Determination of loss of mineral in mining. Accidents to men. Two full courses.

203-204—Mining Plant. Critical study of rock drilling, or coal cutting, or hoisting, or haulage, or ventilating plant at some mine or mines. Determination of efficiency and conditions affecting same. Two full courses.

207-208—Ore Dressing. Critical study of some detail of the ordinary dressing methods, crushing, or screening, or classification, or jigging, or slime treatment, or dry concentration, or magnetic separation, or milling of gold or silver ores, or mechanical preparation of coal. Determination of efficiency, and of conditions essential to success. Two full courses.

213-214—Economic Studies in Mining. Study of existing conditions affecting the production and cost of some mineral or metal, as, for example, anthracite coal, copper, or gold. Two full courses.

PHYSICAL EDUCATION

A1-A2—Physical Education. 6 lectures on personal hygiene during January. 2 hours a week of athletics and elementary graded gymnastic exercises during the whole year, except January. Mr. Fette and Assistants.

B1-B2—Physical Education. 6 lectures on public and personal hygiene during January. 2 hours a week of athletic and gymnastic exercises during the whole year, except January. Students must report at the gymnasium office within two days after the opening of the semester and fill out cards indicating the branch of athletics in which they intend to satisfy the requirements of the course. Professor Meylan, Dr. Elliott and Assistants.

Note—Students getting a grade of B or better in Physical Education A are **not required to take Physical Education B1-B2.**

PHYSICS AND MECHANICS

Mechanics 1—Statics. 2 hours. Professors BURNSIDE and SCHROEDER, Dr. WEBB and Mr. WHITTEMORE.

Class is divided into small sections for recitations. Coplanar Statics is treated by both algebraic and graphical methods. Text: Maurer's *Technical Mechanics.*
Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 3-4—General Physics: Mechanics, Wave-Motion, Heat and Light. 3 lectures and 2 recitations. Professor WENDELL, Dr. MORSE, Mr. FARWELL, Dr. WEINRICH, Mr. SEVERINGHAUS, Dr. STIFLER, Mr. SCOTT, Mr. BRAININ.

Mechanics—Newton's laws of motion; accelerated linear and angular motions; dimensions; systems of weights and measures; energy, work, power; transformations of energy; conservation of energy; curvilinear motion with applications; gravitation; linear and angular simple harmonic motion; pendulum; wave-motion; sympathetic vibrations; elements of hydrostatics.
Heat—Nature of heat; expansion; thermometry; calorimetry; specific heat; mechanical equivalent of heat; change of state; saturated vapors and hygrometry; continuity of state; conduction; convection; radiation.
Light—General discussion of wave-theory; reflection; refraction; total reflection; index of refraction and measurement; lenses; dispersion; spherical and chromatic aberration; optical instruments; photometry; color; fluorescence and phosphorescence; radiant energy; spectrum analysis; polarization of light.
Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 5—Electricity. 3 lectures and 2 recitations. Professor WENDELL and instructors.

Phenomena of electrostatics; capacity and condensers; electrometers; current electricity and methods of production; Ohm's law with applications; Joule's law with applications; thermo-electricity; magnetic action of currents with applications; electrical units; electro-magnetic induction; inductance.
Required of all second year students in Engineering. Pre-requisite: Physics 3-4.

Physics 43-44—Physical Laboratory. 3 consecutive hours a week throughout the year. Professor WENDELL, Dr. MORSE, Dr. WEINRICH, Mr. SEVERINGHAUS, Dr. STIFLER, Mr. SCOTT, Mr. BRAININ, Mr. MURPHY, Mr. WRIGHT.

This course consists of quantitative experiments with reports in mechanics, light, heat, electricity, and magnetism. Methods of computation, plotting and the precision of measurements are discussed in connection with the experiments.
Pre-requisite: Physics 3-4. Parallel: Physics 5.

Physics 55—Physical Measurements. 2 hours. Professor HALLOCK.

Critical discussion of physical measurements and computations.
Pre-requisite: Physics 3-4. Parallel: Physics 5.

Mechanics 102—Mechanics. 5 hours. Professors BURNSIDE and SCHROEDER, Dr. WEBB, and Mr. WHITTEMORE.

This course is a continuation of Mechanics 1, using the same text book. The class is divided into small sections for recitations. Statics is completed; centers of gravity and moments of inertia of areas treated with aid of calculus; displacement, velocity, acceleration, motions of translation and rotation, work and energy, power, efficiency, impulse and momentum are all treated with special reference to engineering problems.
Required of all second year students in Engineering. Pre-requisite: Mechanics 1, Physics 3, and Mathematics 64-65.

Mechanics 105—Thermodynamics. 2 hours. Professors WILLS and PEGRAM.

An idea of the nature of the course may be obtained from the following topical headings: The nature of heat; thermometry; calorimetry; heat and work diagrams; the First Law; applications to gases, perfect and actual; the work of Carnot; the

Second Law; the Kelvin absolute scale of temperature; the combination of the two laws; application to the problem of change of state; the properties of saturated and superheated steam; theory of the "plug experiment"; the flow of fluids from orifices.

Pre-requisite: Physics 4 and Mechanics 102.

Mechanics 107-108—Theory of Electricity and Magnetism. 2 hours first half-year, 3 hours second half-year. Professor WILLS.

The fundamental principles of electricity and magnetism are developed and discussed with particular reference to the bearing which they have in relation to the science of electrical engineering. The course concludes with an introduction into the theory of alternating currents.

Pre-requisite: Physics 5 and Mathematics 64-65.

Mechanics 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits. 4 hours first half-year, 3 hours second half-year. Professor PUPIN.

Pre-requisite: Mechanics 107-108.

Physics 52—Conduction of Electricity in Gases. 5 2-hour lectures. Professor DAVIS.

Mathematical Physics 201—Vector Analysis and Mathematical Introduction. 4 hours. Professor WILLS.

Mathematical Physics 203-204—Partial Differential Equations of Physics. 2 hours. Dr. WEBB.

Laplace's Equation; Poisson's Equation; Equation of Heat Conduction; Telegrapher's Equation; Fourier's Series; Spherical Harmonics; Bessel's Functions.

Mathematical Physics 206—Mechanics. 4 hours. Professor WILLS.

An advanced course on Mechanics developed with special reference to the general methods of d'Alembert, Lagrange, Jacobi and Hamilton.

Mathematical Physics 208—Elasticity. 2 hours. Professor WILLS.

Mathematical Physics 215-216—Electricity and Magnetism and Electro-Magnetic Theory of Light. 2 hours. Professor PUPIN.

Mathematical Physics 223-224—Recent Advances in Electrical Theory. 2 hours. Professor PUPIN.

For other courses in experimental and mathematical physics the student is referred to the *Announcement of the Division of Mathematical and Physical Science.*

SHOP WORK

The shop work is done in the Macy Building, which has full modern equipment, including the best types of improved machine tools for wood working and metal working in shops that provide for groups of twenty to twenty-four students to a section.

Shop work in wood is planned to lead up to pattern making and foundry work. The equipment includes benches for joinery and pattern making with the necessary hand tools and individual speed lathes for wood turning, a motor-head speed lathe of large size, 36-inch band saw and trimmers of the most recent type. There are also available for working up stock and special projects a saw bench, surfacer, jointer, mortising machine, all of the latest type.

Shop work in metal includes foundry, forging and machine-shop practice. The foundry contains molding benches for twenty students, and necessary tools for all kinds of bench work in snap flasks, floor

molding, loam work, and the application of sweeps to the making of molds, together with melting pits for the melting of brass and bronzes and a cupola for melting cast iron. In the forge shop there are twenty forges with anvils, tools and vises, a 30-pound Bradley power hammer and a 400-pound Billings and Spencer drop-press. The machine shop contains lathes, swinging from twelve to twenty inches, planers, drill-presses, universal milling machines, and grinding machines, with examples of direct-connect motor and belt drives for each. A Jones and Lamson flat turret-lathe and a Warner and Swasey screw machine are used for demonstrating modern methods of economical repetition production. In conjunction with all the shops there is a well-equipped tool-room, the attendance record is kept by a time-keeper's recording clock, and the organization and atmosphere of a commercial shop are aimed at.

1—Wood-turning and Pattern-making. 2 afternoons. Mr. CONSTANTINE.

Shopwork, demonstrations and shop visits. The construction of typical patterns and core boxes, solid, split and piece, involving the use of bench tools and turning lathe. Second year students in Mechanical Engineering.

2—Molding and Foundry Practice. 1 afternoon. Professor SLEFFEL.

Shopwork, demonstrations and shop visits. Bench molding with type patterns, swept work in green sand and loam and molding in dry sand. Second year students in Mechanical Engineering.

10S—Machine Work. Mr. WALSH.

As below. Mechanical Engineering. Section I, three weeks in June; Section II, three weeks in September. Second year.

11—Machine Work. 2 afternoons. Mr. WALSH.

Shopwork, demonstrations and shop visits. Practical work with the lathe, planer, drill, shaper, milling machine, grinder and turret lathe. Assembling, erection and rigger's work. Third year students in Mechanical Engineering.

Pre-requisite: Shopwork 10S.

12—Forging. 2 afternoons. Professor SLEFFEL.

Shopwork, demonstrations and shop visits. Management of fire, shaping, drawing, upsetting, swaging, welding, tempering and die-forging. Work on drop and helve hammers. Second year students in Mechanical Engineering.

13-14—Machine Work. 1 afternoon. Mr. WALSH.

As above. Second year students in Electrical Engineering.

15—Forging and Foundry Practice. 1 afternoon. Professor SLEFFEL.

As above. Second year students in Civil Engineering.

16—Machine Work. 1 afternoon. Mr. WALSH.

As above. Second year students in Civil Engineering.

18S—Pattern-making, Forging, and Machine Work. Three weeks in June. Professor SLEFFEL, Mr. CONSTANTINE and Mr. WALSH.

As above. Second year students in Chemical Engineering.

SCHEDULE OF PRE-REQUISITES FOR SUBJECTS UNDER THE FACULTY OF APPLIED SCIENCE

Subject	Pre-requisite
Astronomy	
105—Geodesy. (For C. E.)	Math. 64-65 (Differential and Integral Calculus)
106—Geodesy. (For C. E.)	Astron. 105 (Geodesy)
107S—Geodetic Surveying (For C. E.)	Astron. 106 (Geodesy)
Botany	
7—Growth and Character of Timber	
Chemistry	Pre-requisite
3-4—General Inorganic	Entrance Chemistry or Chem.A.
101-102—Advanced Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis) Chem. 163-4 (Quantitative Analysis)
121-122—Physical Chemistry	Chem. 3 or 4 (General Inorganic); 61 or 62 (Quantitative Analysis) Phys. 3-4-5 (Elementary Mechanics and General Physics) Math. 64-65 (Differential and Integral Calculus)
125-126—Physical Chemistry	See 121-122
41-42—Organic, lectures	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis)
43M—Organic laboratory	Chem. 3 or 4 (General Inorganic) Chem. 41-42 (Organic) or parallel
141-142—Organic, general	Chem. 41-42-43M (Organic) Chem. 161-162 (Quantitative Analysis, Inorganic)
143-144—Organic, conferences	Chem. 141-142 (Organic) or parallel
49—Advanced Organic (For Chem. E.)	Chem. 41-42 (Organic)
61 or 62—Qualitative Analysis	Entrance Chemistry or Chem.A. *Parallel* Chem. 3-4 (General Inorganic)
65—Quantitative Analysis Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
66—Quantitative Analysis Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis)
161-162—Quantitative Analysis Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis)
163-164—Quantitative Analysis	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
167-168—Advanced Inorganic Analysis	Chem. 101-102 (Advanced Inorganic) Chem. 121-122 (Physical Chemistry) Chem. 163-164 (Quantitative Analysis)
171—Organic Analysis	Chem. 41-42 (Organic) Chem. 161-162 (Quantitative Analysis, Inorganic)
175—Food Analysis	Chem. 41-42, 161-162
176—Chemistry of Food and Nutrition	Chem. 41 (Introductory Organic)
76—Microscopical Analysis	Chem. 65
78—Sanitary Biological Analysis	Chem. 65, 76
79—Sanitary Bacteriological Analysis	Chem. 65, 76
81-82—Industrial Chemistry, general course	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
83—Industrial Chemistry, special course	Chem. 81-82 (Industrial Chemistry) and Chem. 41 (Elementary Organic)
84—Food Chemistry	Chem. 3 or 4 (General Inorganic) Chem. 81-82 or 41-42
88—Industrial Chemistry, laboratory practice	Chem. 3 or 4 (General Inorganic) Chem. 41-42 (Elementary Organic) Chem. 163-4 (Quantitative Analysis)
89—Industrial Chemistry, laboratory practice	Chem. 61 or 62 (Qualitative Analysis)

95-96—Industrial Chemistry 197—Chemical Factory Machinery and Apparatus 198—Chemical Factory Apparatus and Machines 80a—Factory Inspection. (For Chem. and Chem. E.) (Second Year) 80b—Factory Inspection and Summer Factory Work. (For Chem. E.) (Third Year)	Chem. 3 or 4 Chem. 61 or 62 Chem. 41-42 Chem. 65 or other Quantitative
93-94—Electro-Chemistry 181 or 182—Practical Electro-Chemistry	Chem. 3 or 4 (General Inorganic) Chem. 61-62 (Qualitative Anaylsis) Chem. 65 (Quantitative Analysis)
183-184—Industrial Electro-Chemistry	Chem. 3-4 (General Inorganic) Chem. 65 (Quantitative Analysis, Inorganic)

Civil Engineering

2—Theory of Surveying	
15—Surveying (between First and Second Years)	C.E. 2 (Theory of Surveying)
21—Highway Engineering	
23—Theory of Railroad Surveying	C.E. 15 (Surveying)
25—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
26—Surveying (between Third and Fourth Years)	C.E. 25 (Surveying)
27—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
28—Surveying (between Second and Third Years)	C.E. 23 (Theory of Railroad Surveying) C.E. 27 (Surveying)
51-52—Theory of Railroad Surveying	C.E. 15 (Surveying)
53-54—Elasticity and Resistance of the Materials of Engineering	Mech. 102 (Analytical Mechanics)
57a—Statistics and Interpretation of Water Analysis 57b—Drainage of Marshes and Lowlands	Chem. 78 (Sanitary Biological Analysis) Chem. 79 (Sanitary Bacteriological Analysis) C.E. 59 (Sanitary Engineering)
58—Masonry Structures	Mech. 102 (Analytical Mechanics) Min. 5 (Minerals of Building Stones)
59—Sanitary Engineering	Chem. 82 (Industrial Chemistry)
61—Analytical Theory of Trusses	Mech. 102 (Analytical Mechanics)
62—Graphic Statics	Mech. 102 (Analytical Mechanics)
64—Graphic Statics (abridged course)	Mech. 102 (Analytical Mechanics)
71—Surveying (between Third and Fourth Years)	C.E. 51-52 (Theory of Railroad Surveying) C.E. 25 (Surveying)
75—Hydraulics	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
76—Hydraulics. (For E.M.) (C.E. 75 abridged)	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
77—Hydraulics. (For E.E.)	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
78—Hydraulics. (For Chem. E. and M. E.)	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
85—Foundations	C.E. 58 (Masonry Structures) Geol. 18 (General Geology)
87-88—The Design and Construction of Bridges, Roofs and Buildings. (For Sanitary Engs.)	C.E. 53-54 (Elasticity and Resistance of the Materials of Engineering) C.E. 61 (Analytical Theory of Trusses) C.E. 62 (Graphic Statics)
89-90—Railroad Engineering	C.E. 71 (Surveying)
94—Design and Construction of Sewers, and River and Harbor Improvements	C.E. 75 (Hydraulics) C.E. 59 (Sanitary Engineering) C.E. 26 (Surveying)
96—Principles of Hygiene, Sanitary Science and Public Health	Chem. 78 (Sanitary Biological Analysis) Chem. 79 (Sanitary Bacteriological Analysis) C. E. 59 (Sanitary Engineering) 57a (Statistics and Interpretation of Water Analysis) 57b (Drainage of Marshes and Lowlands)

Subject	Pre-requisite
97—Water-Supply and Irrigation Engineering 99-100—Graduation Thesis	C.E. 26 (Surveying) C.E. 59 (Sanitary Engineering) C.E. 75 (Hydraulics)
Drafting	
1 or 2—Elements of Mechanical Drafting	
3 or 4—Descriptive Geometry	
5 or 6—Graphics	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
7 or 8—Structural Drafting	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
Economics	
2—Introduction to Economics	
Electrical Engineering	
2—Elements of Dynamo Electric Machinery	Phys. 3, 4 and 5 (Elements of Electrical Engineering)
4—Electric Distribution (For E.M. Met.E. and C.E.) *Parallel* E.E. 72 (Direct Current Laboratory)	E.E. 2. (Elements of Dynamo Elect. Mach'y) Phys. 5
52—Design of Direct Current Machinery	E.E. 2 and 101 (Elements of Dynamo Elect. Machinery)
54—Design of Alternating Current Machinery *Parallel* Mech. 110 (Th. of Variable Currents) and E.E. 175-176	E.E. 52, 103 and 105, Mech. 108
72—Direct Current Laboratory *Parallel* E.E. 4 (Electric Distribution)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43-44 (Phys. Laboratory)
73—Direct Current Laboratory. (For M.E.) *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43-44 (Phys. Laboratory)
75—Alternating Current Laboratory. (For E.M. and M.E.) (Short course)	E.E. 4 or 104 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
76—Alternating Current Laboratory. (For C.E.)	E.E. 4 or 104 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
98—Thesis (Optional) *Parallel* Subjects of Fourth Year	All courses
101—Generator and Motor Practice *Parallel* E.E. 73 *or* 173-174 (Direct Current Laboratory)	E.E. 2 (Elements of Dynamo Elect. Mach'y) and Phys. 5
103—Electric Motors. (For E.E.)	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
103A—Electric Motors. (For M.E.)	E.E. 104 (Electric Distribution) E.E. 73 (Direct Current Laboratory)
104—Electric Distribution	Phys. 5 and E.E. 2 and E.E. 101
105—Alternating Current Engineering. (For E.E.)	E.E. 104 (Electric Distribution) E.E. 101
105A—Alternating Current Engineering. (For M.E.)	E.E. 104 (Electric Distribution) E.E. 101 (Dynamo and Motor Practice)
106—Electric Plants	E.E. 104 and 105 (Electric Distribution)
108—Plant Inspection *Parallel course* E.E. 105	E.E. 104 (Electric Distribution) E.E. 173-174
109-110—Telegraphy and Telephony 112—Electric Railways	E.E. 104 For E.E. students E.E. 104, 173-174 For C.E. students E.E. 4, 72 and 75
173-174—Direct Current Laboratory *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of the Dynamo) Phys. 5 and 43-44

Subject	Pre-requisite
175-176—Alternating Current Laboratory	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
Parallel Mech. 109 (Theory of Alternators and Transformers), Mech. 110 (Theory of Variable Currents), E.E. 103 (Electric Motors) and 105 A. C. Eng.	E.E. 173-174 (Direct Current Laboratory)
177—Instrument Laboratory	

Geology

4—Petrography	Min. 6 (Optical Mineralogy)
5-6—General Geology	Min. 1-2 (Descriptive and Determinative Mineralogy) Parallel course
16—Index Fossils	Geol. 5-6 (General Geology)
18—General Geology	Min. 5 (Minerals of Building Stones)
20—Rocks and Soils	Geol. 18 (General Geology) *or* Geol. 5-6 (General Geology)
51—Principles of Geology	Geol. 5-6 (General Geology) *or* Geol. 18 (General Geology)
52—Discussion of Secondary Structural Features	Geol. 5-6 (General Geology) *or* Geol. 18 (General Geology)
101—Applied Petrography	Geol. 4 (Petrography)
102—Petrography of the Ores	Geol. 4, 101, 105-106 (Petrography and Economic Geology)
105-106—Economic Geology	Geol. 5-6 (General Geology)
107-108—Invertebrate Palæontology	Antecedent work in Geology
110—Geological Examinations and Surveys	Geol. 105-106 (Economic Geology)
112—Field Geology	Geol. 5-6 (General Geology) Geol. 105-106 (Economic Geology) *desirable, not prerequisite*
201-202—Petrology	Geol. 4 (Petrography)
205-206—Comparative Geology	Geol. 5-6 (General Geology) Geol. 16 (Index Fossils)

Law

2—Business Law	

Mathematics

1 (or 2)—Algebra	Entrance Mathematics
64 (or 67)—Calculus	Math. 3 (Anal. Geometry) or Math. 4
3 (or 4)—Analytical Geometry	Entrance Mathematics
65 (or 68)—Calculus	Math. 3 or 4 (Anal. Geometry) and Math. 64 or 67 (Calculus)

Mechanical Engineering

11-12—Steam Power Machinery. (For M.E. and Ch.E.) 13-14—Steam Power Machinery (Short M.E. 11-12) (For other than M.E. and Ch.E.)	Phys. 3-4 (General Physics)
17-18—Engineering Thermodynamics	M.E. 11-12 (Steam Power Machinery) *or* M.E. 13-14 (Steam Power Machinery) Mech. 102 (Analytical Mechanics)
19-20—Engine Design	M.E. 39-40 (Machine Design) M.E. 11-12 (Steam Power Machinery) M.E. 17-18 (Eng. Thermodynamics)
21—Gas Power	M.E. 19 (Engine Design) M.E. 33 (Standard Tests and Research Methods)
25-26—Steam Power	M.E. 96S (Steam Power Plant Summer Work)
31-32—Standard Tests and Research Methods	M.E. 11-12 (Steam Power Machinery)
Parallel M.E. 17-18 (Engineering Thermodynamics) 33—Standard Tests and Research Methods (Continuation of M.E. 31-32)	M.E. 17-18 (Eng. Thermodynamics) M.E. 31-32 Std. Tests and Research Methods M.E. 96S (Steam Power Plant Summer Work)

Subject	Pre-requisite
35-36—Kinematics of Machinery	Math. 3-4 (Analytical Geometry)
37—Machine Design	Drafting 7
39-40—Machine Design *Parallel* C.E. 53	M. E. 35-36 (Kinematics of Machinery)
41—Machine Design (Short course of M.E. 39-40) *Parallel* C.E. 53 for E.E.	
(For E.E.)	M.E. 35-36 (Kinematics of Machinery)
(For C.E.)	M.E. 78 (Kinematics of Machinery) C.E. 53
45-46—Hydraulic Turbines (For M.E.)	M.E. 33, 36, 60 C.E. 78
(For C.E.)	M.E. 63, 77, 78 C.E. 75
52—Organization and Management	M.E. 54 M.E. 94S
50—Steam Turbines. (For M.E.)	M.E. 17-18 (Eng. Thermodynamics) M.E. 31-32 (Standard Tests, etc.)
53—Steam Turbines. (For E.E.)	M.E. 17-18 (Eng. Thermodynamics) M.E. 76 (Standard Tests, etc.)
54—Shop Processes	M.E. 94S (Shop and Factory: Summer Work), T. C. Shop work M.E. 39 (Machine Design)
56—Hydraulic Turbine Installations *Parallel* M.E. 60 (Hydraulic Laboratory)	C.E. 77 (Hydraulics)
59—Empiric Design	Draft. 1 or 2 (Elements of Mechanical Drafting)
60—Hydraulic Laboratory. (For E.E.) *Parallel* (For M.E.) C.E. 78. (Hydraulics)	C.E. 77 (Hydraulics)
63—Hydraulic Laboratory *Parallel* C.E. 75 (Hydraulics)	
64—Air Machinery	M.E. 17 (Eng. Thermodynamics)
66—Elevators and Conveyors	M.E. 39 (Machine Design)
70—Pumping Machinery *Parallel* C.E. 78 (Hydraulics)	M.E. 17 (Eng. Thermodynamics)
72—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
74—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
76—Standard Tests. (For E.E., Chem.E. and Met.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Eng. Thermodynamics)
77—Standard Tests. (For C.E., Chem.E.)	M.E. 13-14 (Steam Power Machinery) M.E. 17 (Eng. Thermodynamics)
(For E.E.)	M.E. 17-18 (Eng. Thermodynamics)
78—Kinematics	Math. 3-4 (Analytical Geometry)
80—Experimental Mechanical Laboratory *Parallel course* M.E. 14	M.E. 13
82—Heating and Ventilation	M.E. 17 (Eng. Thermodynamics)
94S—Shop and Factory Summer Work	Sh.Wk. 1 (Wood Turning and Pattern Making) Sh.Wk. 2 (Molding and Foundry Practice) Sh.Wk. 12 (Forging)
96S—Steam Power Plant Summer Work	M. E. 31-32 (Standard Tests, etc.)
97—Mechanical Apparatus for Chemical Factories	M.E. 17-18 (Eng. Thermodynamics) M.E. 11 and 12 M.E. 17 and 18

Metallurgy

101—General Metallurgy	Phys. 3-4-5 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
111—Metallurgy of Copper	Met. 101 (General Metallurgy)
118—Metallurgy of Copper. (Advanced Course)	Met. 111 (Metallurgy of Copper)
122—Metallurgy of Lead, Silver, Gold and Zinc	Met. 111 (Metallurgy of Copper)

Subject	Pre-requisite
128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. (Advanced Course)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
131—Metallurgy of Iron and Steel Prerequisite or *Parallel* Met. 101 (General Metallurgy)	Phys. 3-4-5 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
134—Metallurgy of Iron and Steel	Phys. 3-4-5 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
138—Metallurgy of Iron and Steel. (Advanced Course)	Met. 131 (Metallurgy of Iron and Steel)
141—Electrometallurgy	Phys. 3-4-5 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
148—Electrometallurgy. (Advanced Course)	Met. 141 (Electrometallurgy)
151—Constitution and Properties of Alloys *Parallel* Met. 131 (Met. of Iron and Steel)	Met. 111 (Metallurgy of Copper)
155-6—Metallography of Iron, Steel and Industrial Alloys	Met. 131 (Met. of Iron and Steel) *or* Met. 134 (Metallurgy of Iron and Steel)
158—Constitution and Properties of Alloys. (Advanced Course)	Met. 151 (Constitution and Properties of Alloys)
72—Metallurgical Laboratory *Parallel* Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)	Met. 111 (Metallurgy of Copper)
171—Metallurgical Laboratory *Parallel* Met. 101 (General Metallurgy) and Met. 111 (Metallurgy of Copper)	
172—Metallurgical Laboratory	Met. 171 (Metallurgical Laboratory)
173-174—Metallurgical Laboratory	Met. 171 (Metallurgical Laboratory)
175—Metallurgical Investigation *Parallel* Met. 131 (Metallurgy of Iron and Steel, and Met. 141 (Electrometallurgy)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
77—Met. Plant Construction	Draft. 3-4, 7-8 C.E. 53; Met. 122, 64S and 66S
62S—Summer Course in Non-Ferrous Metallurgy	
64S—Summer Course in Ferrous Metallurgy	Met. 101 (General Metallurgy)
66S—Summer Course in Non-ferrous Metallurgy	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
82S—Summer School in Assaying	Chem. 3-4 and 61-62 Mineralogy 1-2, or 7-8
81—Assaying	Chem. 3-4 and 61-62
182—Assaying	Mineralogy 1-2, or 7-8
188—Assaying	Met. 81 or 182

Mineralogy

1-2—Descriptive and Determinative Mineralogy	Entrance Chemistry Entrance Physics
5—The Minerals of Building Stones	Entrance Chemistry Entrance Physics
6—Optical Mineralogy	Min. 5 (Minerals of Building Stones) *or part of* Min. 1-2 (Descriptive and Determinative Mineralogy) *or equivalent*
7-8—Descriptive and Determinative Mineralogy. (Modification of Min. 1)	Entrance Chemistry Entrance Physics
10—Mineralogy and Crystallography	Min. 15-16
15-16—Determinative Mineralogy	Entrance Chemistry Entrance Physics

Mining

51—Excavation and Tunneling.	Entrance Mathematics Entrance Chemistry Entrance Physics

Subject	Pre-requisite
52—Boring and Shaft Sinking	E.M. 51 (Excavation and Tunneling)
53—Excavation, Tunneling, Boring and Shaft Sinking. (For C.E.) (Condensation of E.M. 51 and 52)	Entrance Mathematics Entrance Chemistry Entrance Physics
54—Exploration, Development, and Methods of Working. (For E.M. and Met.E.)	Geol. 5-6
Prerequisite or *Parallel*	Geol. 105-106 (Economic Geology) E.M. 51 and 52 (Excavation and Tunneling, Boring and Shaft Sinking)
56—Mine Engineering	E.M. 54
Prerequisite or *Parallel*	E.M. 71-72 (Mine Plant) C.E. 76 (Hydraulics) C.E. 28 (Surveying)
71-72—Mine Plant	E.M. 51-52 E.M. 54 (Exploration, Development and Methods of Working) M.E. 13-14 (Steam Power Machinery)
73—Mine Constructions. (For E.M. and Met.E.)	
75—Design of Mine Plant	Draft. 3-4, 7-8 (Structural Drafting)
Parallel E.M. 71-72 (Mine Plant)	C.E. 53 (Elasticity and Resistance of Materials) Mining 59
77-78—Graduating Thesis or Project	All required subjects in Mining
80—Mill Constructions	M.E. 13-14 (Steam Power Machinery)
81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. (For E.M. and Met.E.)	Min. 1-2 (Descriptive and Determinative Mineralogy) Phys. 3-4 (Elementary Mechanics and General Physics) Mech. 102 (Analytical Mechanics)
82—Ore-Dressing Laboratory. (For E.M. and Met.E.)	E.M. 81 (Ore Dressing, Milling, and the Mechanical Preparation of Coal)
91—Mine Administration. (For E.M. and Met.E.)	E.M. 54 (Exploration, Development and Methods of Working)
94—Mining Law. (For E.M. and Met.E.)	C.E. 27 (Surveying) E.M. 54 (Exploration, Development and Methods of Working)
58—Summer Class in Mine Surveying	C.E. 27 (Surveying)
59—Summer Course in Practical Mining	M.E. 13-14 (Steam Power Machinery) E.M. 54 (Exploration, Development and Methods of Working) E.M. 51 and 52 C.E. 15 and 27 Geol. 105-106

Physical Education

A1-A2 B1-B2	Phys. Ed. A1-A2

Physics and Mechanics

Mech. 1—Mechanics: Statics.	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 3-4—General Physics: Mechanics, Wave-motion, Heat and Light	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 5—Electricity	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 43-44—Physical Laboratory *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 55—Physical Measurements *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Mech. 102—Mechanics	Mech. 1 (Mechanics: Statics)

Subject	Pre-requisite
	Phys. 3 (Mechanics, Wave-Motion, and first part of Heat) Math. 64 and 65 (Differential and Integral Calculus)
Mech. 105—Thermodynamics	Phys. 4 and Mech. 102 (Mechanics)
Mech. 107-108—Theory of Electricity and Magnetism	Phys. 5 and Math. 64-65
Mech. 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits	Mech. 107-108 (Theory of Elecricity and Magnetism)

Shop Work

1—Wood-turning and Pattern Making. (For M.E.)	
2—Molding and Foundry Practice. (For M.E.)	
10S—Machine Work. (For M.E.)	
11—Machine Work. (For M.E.)	Shop Work 108 (Machine Work)
12—Forging. (For M.E.)	
13-14—Machine Work. (For E.E.)	
15—Forging and Foundry Practice. (For C.E.)	
16—Machine Work. (For C.E.)	
18S—Pattern-making. (For Chem.E.)	

SCHOOLS OF MINES, ENGINEERING AND CHEMISTRY

UNIFORM CURRICULUM FOR FIRST CLASS 1913-1914

NOTE: Class to be divided alphabetically.

	HOURS	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Division A: Names A—?	9—10	Mech. 1. Sec. II. 609, 615 F, 703 Hm, 405 A Phys. 3. Sec. I. 510, 604 F, 507 J Phys. 4. 301 F	Phys. 3. 309 H Phys. 4. 510, 615 F, 303, 516, 517, 703 Hm	Phys. 4. 301 F	Phys. 3. 309 H Phys. 4. 510, 615 F, 303, 516, 517, 703 Hm	Mech. 1. Sec. II. 609, 615 F, 703 Hm, 405 A Phys. 3. Sec. I. 510, 604 F, 507 J Phys. 4. 301 F	Phys. 3. 309 H C. E. 2. 309, 511 H, 510 F
	10—11	Math. 3. 402, 406, 602, 609 ¶¶Math. 64. 202, 203, 213 Hm	Math. 1. 309, 408, 307 Hm ¶Math. 64. 202, 203, 213 Hm	Math. 3. 402, 406, 602, 609 ¶¶Math. 64. 202, 203, 213 Hm	Math. 1. 309, 408, 307 Hm ¶¶Math. 64. 202, 203, 213 Hm	Math. 3. 402, 406, 602, 609 ¶Math. 64. 202, 203, 213 Hm	Chem. 3, 61. 309, 311 H Dft. 4. 301 E. 203, 213 Hm
	11—12	Chem. 3, 61. 309, 311 H	Mech. 1. Sec. I. 510, 615 F, 717 Hm, 713 J Phys. 3. Sec. II. 613 F, 517, 616 Hm Dft. 4. 301 E, 203, 213 Hm	Chem. 3, 61. 309, 311 H C. E. 2. 302, 402 E, 603 J	Mech. 1. Sec. I. 510, 615 F, 717 Hm, 713 J Phys. 3. Sec. II. 613 F, 517, 616 Hm Dft. 4. 301 E, 203, 213 Hm	Chem. 3, 61. 309, 311 H	Chem. 3, 61. 309, 311 H
	1—2	Dft. 2. 302 E					
	1—4	Chem. 3, 61, Lab. 515 H Dft. 2. 601 E	Chem. 3, 61, Lab. 515 H Dft. 2. 601 E	Chem. 3, 61, Lab. 515 H Dft. 2. 601 E	Chem. 3, 61, Lab. 515 H Dft. 2. 601 E	Chem. 3, 61, Lab. 515 H Dft. 2. 601 E	
	4—5	Phys. Ed. A1-A2 (Gym.)		Phys. Ed. A1-A2 (Gym.)			
Division B: Names ?—Z	9—10	Math. 3. 203, 213, 214, 717 Hm ¶¶Math. 64. 203, 213, 214 Hm	Phys. 3. 309 H ¶Math. 64. 203, 213, 214 Hm	Math. 3. 203, 213, 214, 717 Hm ¶¶Math. 64. 203, 213, 214 Hm	Phys. 3. 309 H ¶Math. 64. 203, 213, 214 Hm	Math. 3. 203, 213, 214, 717 Hm ¶¶Math. 64. 203, 213, 214 Hm	Phys. 3. 309 H C. E. 2. 309, 511 H, 510 F
	10—11	Mech. 1. Sec. V. 510, 613 F Phys. 4. 301 F	Dft. 3. 306 E, 503, 516 Hm Phys. 4. 510, 615 F, 303, 516, 517, 703 Hm	Mech. 1. Sec. IV. 510, 613 F Phys. 3. Sec. III. 604, 609 F, 511 H Phys. 4. 301 F	Dft. 3. 306 E, 503, 516 Hm Phys. 4. 510, 615 F, 303, 516, 517, 703 Hm	Mech. 1. Sec. V. 510, 613 F Phys. 4. 301 F	Dft. 3. 306 E, 503, 516 Hm
	11—12	Mech. 1. Sec. III. 510, 613, 615 F Phys. 3. Sec. IV. 604, 609 F, 311 H Chem. 4, 62. 309, 311 H	Math. 1. 303, 307, 309 Hm C. E. 2. 302, 402 E, 603 J	Mech. 1. Sec. III. 510, 613, 615 F Phys. 3. Sec. IV. 604, 609 F, 311 H Chem. 4, 62. 309, 311 H	Math. 1. 303, 307, 309 Hm Chem. 4, 62. 309, 311 H	Mech. I. Sec. IV. 510, 613 F Phys. 3. Sec. III. 604, 609 F, 511 H Chem. 4, 62. 309, 311 H	Chem. 4, 62. 309, 311 H
	1—2	Dft. 1. 302 E					
	1—4	Dft. 1. 601 E Chem. 4, 62, Lab. 515 H	Dft. 1. 601 E Chem. 4, 62, Lab. 515 H	Dft. 1. 601 E Chem. 4, 62, Lab. 515 H	Dft. 1. 601 E Chem. 4, 62, Lab. 515 H	Dft. 1. 601 E Chem. 4, 62, Lab. 515 H	
	4—5		Phys. Ed. A1-A2 (Gym.)		Phys. Ed. A1-A2 (Gym.)		

Math. 2, Room 307 Hm for students not having credit in Math. 1. ¶¶Math. 4, Room 703 Hm at 9 and Room 402 Hm at 10 for students not having credit in Math. 3. A=Avery. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. M=Mines. S=Schermerhorn. U=University. Odd numbered courses given in first term only. Even numbered courses given in second term only.

NOTE: See Uniform Curriculum for First Class

COURSE IN CHEMICAL ENGINEERING, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. 301 F Chem. 82. 301 H	Chem. 41-42. 413 H	Phys. 5. 301 F Chem. 82. 301 H	Chem. 163. 413 H E. E. 2. 302 E	Phys. 5. 301 F Chem. 82. 301 H	Chem. 41-42. 413 H
	10—11	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Chem. 163. 413 H, 402 E E. E. 2. 302 E
	11—12	Chem. 81. 301 H	Phys. 5. 609 F, 713 J Chem. 164. 413 H	Chem. 81. 301 H	Phys. 5. 609 F, 713 J Chem. 164. 413 H, 703 J	Chem. 81. 301 H	Chem. 163. 301, 413 H Chem. 164. 413 H, 512 J
	1—4 Div. A	Chem. 163, Lab. 504 H Mineral. 16. 106 S	Phys. 43, Lab. 410 F Chem. 164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Mineral. 15. 106 S Phys. 44, Lab. 410 F	Chem. 163-164, Lab. 504 H
	1—4 Div. B	Chem. 163, Lab. 504 H Mineral. 16. 106 S	Chem. 163-164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Phys. 43, Lab. 410 F Chem. 164, Lab. 504 H	Mineral. 15. 106 S Phys. 44, Lab. 410 F	Chem. 163-164, Lab. 504 H
	4—5	Phys. Ed. B, Gym., 2 hours a week in sections					
		Shop-work 18s, 3 weeks in June.					
Third Class	9—10	Chem. 101. 511 H E. E. 4. 301 E	Mech. E. 11-12. 301 E	Mech. E. 59. 510 E E. E. 4. 301 E	Mech. E. 11-12. 301 E	Mech. E. 59. 510 E Law 2. 405 K	Chem. 101. 511 H Law 2. 405 K
	10—11	Chem. 83-84. 301 H	E. E. 73. Div. A. 301 U Chem. 102. 301 H	Chem. 83-84. 301 H	Chem. 149. 301 H Chem. 102. 301 H	Chem. 83-84. 301 H	Chem. 149. 301 H E. E. 72. Div. B. 301 M
	11—12	C. E. 53. 402 E, 301, 306 M Met. 182. 301 M	C. E. 53. 402 E, 301, 306 M C. E. 76. 301 M	C. E. 53. 402 E, 301, 306 M Met. 182. 301 M	C. E. 53. 402 E, 301, 306 M C. E. 76. 301 M	C. E. 53. 402 E, 301, 306 M Mech. E. 12. 402 E	Mech. E. 11. 302 E
	1—4 Div. A	C. E. 53. 301 E C. E. 54, Lab. 308 E	Mech. E. 59. 510 E Mech. E. 12. WV	Chem. 149, Lab. 504 H	Chem. 149, Lab. 504 H Met. 182	Chem. 149, Lab. 504 H Met. 182	E. E. 73, Lab. 201 E
	1—4 Div. B	C. E. 53. 301 E	Mech. E. 59. 510 E C. E. 54, Lab. 308 E	Chem. 149 E. E. 72, Lab. 201 E	Chem. 149 Met. 182	Chem. 149 Met. 182	Mech. E. 12, Lab. WV
Fourth Class	9—10	Met. 101, 111. 306 M Chem. 122. 413 H	Chem. 171. 311 H	Met. 101, 111. 306 M Chem. 122. 413 H	Mech. E. 37. 510 E Mech. E. 18. 402 E	Met. 101, 111. 306 M Chem. 122. 413 H	Met. 131. 306 M
	10—11	Chem. 197. 309 H Mech. E. 97. 309 H Chem. 198. 311 H	Chem. 197. 309 H Mech. E. 97. 309 H Mech. E. 76. 302 E	Chem. 197. 309 H Mech. E. 97. 309 H Chem. 198. 311 H	Chem. 197. 309 H Mech. E. 97. 309 H Chem. 184. 311 H	Chem. 197. 309 H Mech. E. 97. 309 H Chem. 198. 311 H	Chem. 171. 511 H Chem. 184. 311 H
	11—12	Chem. 121. 413 H Met. 122. 306 M	Mech. E. 17. 301 E	Chem. 121. 413 H Met. 122. 306 M	Mech. E. 17. 301 E	Chem. 121. 413 H Met. 122. 306 M	Mech. E. 77. 301 E Mech. E. 18. 301 E
	1—4	Mech. E. 37. 510 E Chem. 184, Lab. 102 H	Mech. E. 37. 510 E Mech. E. 76. Div. A. Lab. WV Chem. 122. Div. B. Lab. 410 H	Chem. 171, Lab. 504 H Chem. 122. Div. A. Lab. 410 H Mech. E. 76. Div. B. Lab. WV	Mech. E. 77. Div. A. Lab. WV Chem. 171. Div. B. Lab. 504 H Chem. 88, Lab.	Chem. 171. Div. A. Lab. 504 H Mech. E. 77. Div. B. Lab. WV Chem. 88, Lab.	Chem. 88, Lab.

Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *During December and January. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

NOTE: See Uniform Curriculum for First Class.

COURSE IN CHEMISTRY, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. 301 F Chem. 82. 301 H	Chem. 41. 413 H Chem. 42. 413 H	Phys. 5. 301 F Chem. 82. 301 H	Chem. 163. 413 H E. E. 2. 302 E	Phys. 5. 301 F Chem. 82. 301 H	Chem. 41. 413 H Chem. 42. 413 H
	10—11	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Chem. 163. 413 H, 402 E E. E. 2. 302 E
	11—12	Chem. 81. 301 H	Phys. 5. 609 F, 713 J Chem. 164. 413 H	Chem. 81. 301 H	Phys. 5. 609 F, 713 J Chem. 164. 413 H, 703 J	Chem. 81. 301 H	Chem. 163. 301, 413 H Chem. 164. 413 H, 512 J
	1—4	Chem. 163, Lab. 504 H Mineral. 16. 106 S	Chem. 163, 164, Lab. 504 H	Chem. 163, 164, Lab. 504 H	Chem. 163, 164, Lab. 504 H	Mineral. 15. 106 S Chem. 164, Lab. 504 H	
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	Chem. 101. 511 H Chem. 122. 413 H	Chem. 171. 311 H	Chem. 122. 413 H		Chem. 122. 413 H	Chem. 101. 511 H
	10—11	Chem. 83-84. 301 H	Chem. 183. 511 H Chem. 102. 301 H	Chem. 83-84. 301 H	Chem. 102. 301 H	Chem. 83-84. 301 H	Chem. 171. 511 H
	11—12	Chem. 121. 413 H Met. 182. 301 M	Chem. 175. 311 H Mineral. 10. 516 S	Chem. 121. 413 H Met. 182. 301 M	Chem. 175. 311 H Mineral. 10. 516 S	Chem. 121. 413 H	Chem. 183. 511 H
	1—4	Chem. 121. 414 H Chem. 88, Lab. 414 H	Chem. 183, Lab. 504 H Mineral. 10. 106 S	Chem. 171, Lab. 504 H Chem. 88, Lab. 414 H	Chem. 171, Lab. 504 H Met. 182, Lab.	Chem. 175, Lab. 504 H Met. 182, Lab.	Chem. 175, Lab. 504 H Chem. 88, Lab. 414 H
Fourth Class	9—10	Met. 101, 111. 306 M		Met. 101, 111. 306 M		Met. 101, 111. 306 M	Met. 131. 306 M
	10—11		Chem. 141-142. 413 H		Chem. 141-142. 413 H	Chem. 141-142. 413 H	
	11—12	Met. 122. 306 M		Met. 122. 306 M		Met. 122. 306 M	
	1—4		Chem. 89, Lab. 414 H Chem. 43m, Lab. 405 H *b* Thesis				

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *b* Second term only. *First half of term. †For students not having credit in this subject. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. U=University. Odd numbered courses given in first term only. Even numbered courses given in second term only.

NOTE: See Uniform Curriculum for First Class.

COURSE IN CIVIL ENGINEERING, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Min'g 53. 301 M Chem. 82. 309 H	Mech. E. 13-14. 301 E	Phys. 5. 510, 609 F Chem. 82. 309 H	Mech. E. 13-14. 301 E	Min'g 53. 301 M Chem. 82. 309 H	Bot. 7. Div. A. 505 S Mech. E. 13. Div. B. 302 E Mech. E. 14. Div. A. 302 E Geol. 18. Div. B. 401 S
	10—11	Phys. 5. 301 F E. E. 2. 301 E	Mineral. 5. 516 S Geol. 18. 407 S	Phys. 5. 301 F E. E. 2. 301 E	Mineral. 5. 516 S Met. 134. 306 M	Phys. 5. 301 F Geol. 18. 407 S	Mech. E. 13. Div. A. 302 M Bot. 7. Div. B. 505 S Geol. 18. Div. A. 401 S Mech. E. 14. Div. B. 302 M
	11—12	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F	Phys. 5. 510, 609 F Met. 134. 306 M
	1—2	Dft. 6-8. 402 E	Dft. 5. Div. B. 402 E		Dft. 5. Div. A. 402 E		
	1—4 Div. A	Mineral. 5, Lab. 106 S Dft. 6-8. 601 E	Sh. Wk. 15, Lab. Sec. I, 31 T Phys. 43. Sec. II. 410 F Sh. Wk. 16. Secs. I, II. 125 T Phys. 44. Sec. III. 410 F	Bot. 7 502 S Phys. 44. Secs. I, II. 410 F Dft. 6-8. Sec. III. 601 E	Dft. 5. 601 E Dft. 6-8. Secs. I, II. 601 E Sh. Wk. 16. Sec. III. 125 T	Phys. 43. Sec. I. 410 F Dft. 6-8. 601 E	Sh. Wk. 15, Lab. Sec. II. 31 T Geol. 18, Lab. and fieldwork
	1—4 Div. B	Mineral. 5, Lab. 106 S Dft. 6-8. 601 E	Dft. 5. 601 E Phys. 44, Lab. Sec. IV. 410 F Dft. 6-8. Secs. V, VI. 601 E	Sh. Wk. 15. Sec. III. 31 T Phys. 43. Sec. IV. 410 F Sh. Wk. 16. Sec. V, VI. 125 T Dft. 6-8. Sec. IV. 601 E	Phys. 43. Sec. III. 410 F Sh. Wk. 15, Lab. Sec. IV. 31 T Phys. 44. Sec. V, V. 410 F Sh. Wk. 16. Sec. IV. 125 T	Bot. 7. 502 S Dft. 6-8. 601 E	Geol. 18, Lab. and fieldwork
	4—5	Phys. Ed. B. 2 hrs. a week in sections.					
Third Class	9—10	C. E. 59. 306 E ††E. E. 4. 301 E E. E. 72, Lab. Secs. III, IV. 201 E	Mech. E. 17. Div. A. 301 M C. E. 61. Div. B. 306 M Mech. E. 18. Sec. I, III, IV, 605 J [510 E Mech. E. 78. Secs. II, V, VI.	C. E. 61. Div. A. 402 E Mech. E. 17. Div. B. 306 E E. E. 4. 301 E	C. E. 21. 402 E Mech. E. 78. 510 E	C. E. 59. 306 E E. E. 72. 301 E	Mech. E. 17. Div. A. 302 M Mech. E. 77. Div. B. 301 U Mech. E. 18. Secs. I, III, IV. 402 E
	10—11	Ast. 105. 305 S ††C. E. 58. 301 U [201 E E. E. 72, Lab. Secs. III, IV.	C. E. 51. 301 E C. E. 52. 402 E	Ast. 105. 305 S C. E. 58. 301 U	C. E. 51. 301 E C. E. 52. 402 E	Ast. 105. 305 S C. E. 58. 301 U	Mech. E. 77. Div. A. 301 U Mech. E. 17. Div. B. 511 J C. E. 52. 402 E
	11—12	C. E. 53. 402 E, 301, 306 M ††Mech. E. 18. Sec. II, V, VI. 306 E [201 E E. E. 72, Lab. Secs. III, IV.	C. E. 53. 402 E, 301, 306 M Mech. E. 78. Secs. I, III, IV, 510 E [311 H Mech. E. 18. Secs. II, V, VI.	C. E. 53. 402 E, 301, 306 M Ast. 106. 305 S	C. E. 53. 402 E, 301, 306 M C. E. 62. 402 E	C. E. 53. 402 E, 301, 306 M Mech. E. 78. 510 E	C. E. 61. 402 E C. E. 62. 402 E
	1—4 Div. A	C. E. 53, Lab. 308 E C. E. 54. 402 E. Secs. I, II ††Sec. III	Mech. E. 77, Lab. WV. Secs. I, II C. E. 58. 406 E	Mech. E. 77. Lab. WV Sec. III Ast. 106. 609 F	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53. 301 E E. E. 72, Lab. 201 E. Secs. I, II.—C. E. 54. Sec. III	*C. E. 61. 406 E **C. E. 59, Lab. C. E. 52. 301 E
	1—4 Div. B	C. E. 53. 301 E E. E. 72, Lab. 201 E. Secs. V, VI ††Sec. IV	*C. E. 61. 406 E **C. E. 59, Lab. C. E. 58. 406 E	Mech. E. 77. Lab. WV. Sec. IV Ast. 106. 609 F	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53, Lab. 308 E C. E. 54	Mech. E. 77, Lab. WV. Secs. V, VI C. E. 52. 301 E
Fourth Class	9—10	C. E. 99 C. E. 94. 306 E	C. E. 75. 306 E C. E. 90. 402 E	C. E. 99 C. E. 94. 306 E	C. E. 75. 306 E E. E. 112. 306 E	E. E. 75. 301 E Law 2. 405 K	C. E. 75. 306 E Law 2. 405 K
	10—11	C. E. 85. 402 E C. E. 88. 402 E	C. E. 87. 402 E Mech. E. 46. 301 E	C. E. 85. 402 E C. E. 88. 402 E	C. E. 87. 402 E Mech. E. 46. 301 E	C. E. 97. 306 E C. E. 100	Mech. E. 41. 306 M Mech. E. 46. 301 U
	11—12	C. E. 97. 306 E E. E. 112. 511 H	C. E. 89. 306 E	C. E. 97. 306 E C. E. 100	C. E. 89. 306 E C. E. 90. 306 E	E. E. 5. 302 E C. E. 100	C. E. 89. 306 E C. E. 90. 306 E
	1—4 Div. A	C. E. 100	C. E. 87. 404 E C. E. 90. 404 E	E. E. 75. 202 E C. E. 88. 404 E	Mech. E. 41. 510 E C. E. 100	C. E. 89. 404 E C. E. 100	Mech. E. 63, Lab. WV
	1—4 Div. B	Mech. E. 63, Lab. WV C. E. 100	C. E. 87. 404 E C. E. 90. 404 E	C. E. 88. 404 E	Mech. E. 41. 510 E C. E. 100	C. E. 89. 404 E C. E. 100	E. E. 75

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *Except two afternoons in January. **Two afternoons in January. †For secs. I, II, IV, at 1 to 4 P.M., in Rooms 301, 410, 301 E, respectively. I.—Engineering. F—Faverweather. H—Haverneyer. Hm—Hamilton. J—Journalism. K—Kept. M—Mines. S—Schermerhorn. T—Teachers College. U—University. W—Varick [illegible] given in first [illegible]

NOTE: See Uniform Curriculum for First Class

COURSE IN SANITARY ENGINEERING, 1913-1914

	Hours	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10	Phys. 5. 301 F Chem. 82. 309 H	Mech. E. 13-14. 301 E	Phys. 5. 510, 609 F Chem. 82. 309 H	Mech. E. 13-14. 301 E	Phys. 5. 301 F Chem. 82. 309 H	Bot. 7. 505 S Mech. E. 14. 302 E
	10—11	Chem. 65. 511 H E. E. 2. 301 E	Mineral. 5. 516 S Geol. 18. 407 S	Phys. 5. 301 F E. E. 2. 301 E	Mineral. 5. 516 S Met. 134. 306 M	Chem. 65. 511 H Geol. 18. 407 S	Mech. E. 13. 302 M Geol. 18. 401 S
	11—12	¶Math. 65. 202, 203, 213, Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213, Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213, Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213, Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213, Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	Phys. 5. 510, 609 F Met. 134. 306 M
	1—2	Dft. 8. 402 E	Dft. 5. 402 E				
	1—4	Mineral. 5, Lab. 106 S Dft. 8. 601 E	Dft. 5. 601 E Dft. 8. 601 E	Bot. 7. 502 S Sh. Wk. 16. 125 T	Phys. 43. 410 F Phys. 44. 410 F	Chem. 65, Lab. †Chem. 76	Chem. 65, Lab. Geol. 18. Lab. and fieldwork
	4—5	Phys. Ed. B. 2 hrs. a week in sections.					
Third Class	9—10	C. E. 59. 306 E E. E. 4. 301 E	Chem. 41. 413 H Chem. 78	C. E. 61. 402 E E. E. 4. 301 E	C. E. 21. 402 E Mech. E. 78. 510 E	C. E. 59. 306 E E. E. 72. 301 E	Chem. 41. 413 H Chem. 78
	10—11	Chem. 79 C. E. 58. 301 U	C. E. 51. 301 E C. E. 52. 402 E	Chem. 79 C. E. 58. 301 U	C. E. 51. 301 E C. E. 52. 402 E	C. E. 58. 301 U	C. E. 52. 402 E
	11—12	C. E. 53. 402 E, 301, 306 M	C. E. 53. 402 E, 301, 306 M Mech. E. 78. 510 E	C. E. 53. 402 E, 301, 306 M	C. E. 53. 402 E, 301, 306 M C. E. 62. 402 E	C. E. 53. 402 E, 301, 306 M Mech. E. 78. 510 E	C. E. 61. 402 E C. E. 62. 402 E
	1—4	C. E. 53. 308 E C. E. 54. 402 E	Chem. 79 C. E. 58. 406 E	Chem. 79 Chem. 78	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53. 402 E E. E. 72, Lab. 201 E	*C. E. 61. 406 E **C. E. 59, Lab.
Fourth Class	9—10	C. E. 57 a, b. 301 H C. E. 94. 306 E	C. E. 75. 306 E C. E. 100.	Mech. E. 17. 306 E C. E. 94. 306 E	C. E. 75. 306 E E. E. 112A. 306 E	C. E. 57, a, b. Law 2. 405 K	C. E. 75. 306 E Law 2. 405 K
	10—11	C. E. 85. 402 E	C. E. 87. 402 E C. E. 96.	C. E. 85. 402 E	C. E. 87. 402 E C. E. 96.	C. E. 97. 306 E Mech. E. 76. 512 J	Mech. E. 17. 511 J C. E. 96.
	11—12	C. E. 97. 306 E E. E. 76. 402 E	C. E. 89. 306 E C. E. 90. 306 E (Optional)	C. E. 97. 306 E	C. E. 89. 306 E C. E. 90. 306 E (Optional)	C. E. 100.	C. E. 89. 306 E C. E. 90. 306 E (Optional)
	1—4	Mech. E. 63, Lab. WV E. E. 76. 202 E	C. E. 87. 404 E C. E. 90. 404 E or Chem. 180	Chem. 179 Mech. E.. 76, Lab. WV	Chem. 179 C. E. 100 or Chem. 180	C. E. 89. 404 E C. E. 100.	

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *Except two afternoons in January. **Two afternoons in January. †During February and March. E=Engineering. F=Fayerweather. H=Havermeyer. Hm=Hamilton. K=Kent. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

NOTE: See Uniform Curriculum for First Class

COURSE IN ELECTRICAL ENGINEERING, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. 301 F Chem. 82. 309 H	Mech. E. 13-14. 301 E	Phys. 5. 301 F Chem. 82. 309 H	Mech. E. 13-14. 301 E	Phys. 5. 301 F Chem. 82. 309 H	Phys. 5. 510 F E. E. 2. 301 E
	10—11	Chem. 65. 511 H ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Mech. E. 13. 301 H ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Phys. 55, (105.) 304 F ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Phys. 5. 510 F ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Chem. 65. 511 H ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Phys. 55, (105.) 304 F
	11—12	¶Math. 65. 202, 203, 213 Hm E. E. 2. 301 E	¶Math. 65. 202, 203, 213 Hm Met. 134. 306 M	¶Math. 65. 202, 203, 213 Hm E. E. 2. 301 E	¶Math. 65. 202, 203, 213 Hm Met. 134. 306 M	¶Math. 65. 202, 203, 213 Hm	
	1—2						Mech. E. 14. 511 H
	1—4 Div. A	Chem. 65, Lab. 504 H Sh. Wk. 14. 125 T	Chem. 65, Lab. 504 H Dft. 6-8. 601 E	Sh. Wk. 13. 125 T Dft. 6-8. 601 E	Dft. 5. 601 E Dft. 6-8. 601 E	Phys. 43. 410 F Phys. 44. 410 F	
	1—4 Div. B	Chem. 65, Lab. 504 H Phys. 44. 410 F	Chem. 65, Lab. 504 H Dft. 6-8. 601 E	Phys. 43. 410 F Dft. 6-8. 601 E	Dft. 5. 601 E Dft. 6-8. 601 E	Shop 13-14. 125 T	
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	E. E. 101. 302 E E. E. 104. 302 E	Mech. 107. 604 F Econ. 2. 511 J	E. E. 101. 302 E E. E. 104. 302 E	Mech. 107. 604 F Econ. 2. 511 J	Mech. E. 17. 302 E E. E. 104. 302 E	Mech. E. 41. 512 J E. E. 174, Lab. 201 E
	10—11	Mech. E. 17. 301 E Mech. 108. 604 F	C. E. 77. 302 M Econ. 2. 511 J	Mech. 105. 302 M Mech. 108. 604 F	C. E. 77. 302 M E. E. 52. 502 E	Mech. 105. 302 M Mech. 108. 604 F	E. E. 101. 302 E E. E. 174, Lab. 201 E
	11—12	C. E. 53. 402 E, 301, 306 M E. E. 174. 302 E	C. E. 53. 402 E, 301, 306 M E. E. 52. 502 E	C. E. 53. 402 E, 301, 306 M Mech. E. 18. 306 E	C. E. 53. 402 E, 301, 306 M Mech. E. 76. 605 J	C. E. 53. 402 E, 301, 306 M Mech. E. 18. 306 E	E. E. 174, Lab. 201 E
	1—4 Div. A	Mech. E. 41. 510 E Mech. E. 36. 510 E	Mech. E. 76. WV	E. E. 173, Lab. 201 E	E. E. 173, Lab. 201 E Mech. E. 36. 510 E	C. E. 53. 301 E E. E. 52. 502 E	C. E. 53, Lab. 308 E E. E. 174, Lab. 201 E
	1—4 Div. B	C. E. 53. 301 E Mech. E. 36. 510 E	C. E. 53, Lab. 308 E Mech. E. 76. WV		Mech. E. 41. 510 E Mech. E. 36. 510 E	E. E. 173, Lab. 201 E E. E. 52. 502 E	E. E. 173, Lab. 201 E E. E. 174, Lab. 201 E
Fourth Class	9—10	E. E. 175. Div. A. 202 E Chem. 183. Div. B. 102 H Mech. E. 56. 306 M	E. E. 103. 302 E E. E. 176. Div. A. 202 E E. E. 110. Div. B. 302 E	Mech. E. 53. 301 U E. E. 176. 502 E	Chem. 183. Div. A. 102 H E. E. 175. Div. B. 202 E E. E. 112. 306 E	Mech. E. 53. 301 U E. E. 176. Div. B. 202 E	E. E. 105. 301 E E. E. 54. 306 E
	10—11	E. E. 175. Div. A. 202 E Chem. 183. Div. B. 102 H Mech. 110. 202 Ph	Mech. 109. 202 Ph E. E. 176. Div. A. 202 E E. E. 106. Div. B. 302 M	Mech. 109. 202 Ph Mech. 110. 202 Ph	Chem. 183. Div. A. 102 H E. E. 175. Div. B. 202 E Mech. E. 72. 302 M	E. E. 109. 301 E E. E. 110. Div. A. 301 E E. E. 176. Div. B. 202 E	E. E. 105. 301 E Mech. E. 72. 306 E
	11—12	E. E. 175. Div. A. 202 E Chem. 183. Div. B. 102 H E. E. 112. 511 H	Mech. 109. 202 Ph E. E. 176. Div. A. 202 E	Mech. E. 77. 301 E Mech. 110. 202 Ph	Chem. 183. Div. A. 102 H E. E. 175. Div. B. 202 E E. E. 54. 302 E	E. E. 105. 301 E E. E. 106. Div. A. 302 E E. E. 176. Div. B. 202 E	E. E. 177. 502 E E. E. 106. 302 E
	1—2		E. E. 103. 301 E	E. E. 175. 502 E			
	1—4 Div. A	E. E. 175. 202 E *Mech. 110 **Mech. E. 60. WV	†E. E. 103. 301 E E. E. 176. 202 E	E. E. 177. 501 E E. E. 54. 502 E §Phys. 52	Chem. 183. 102 H Mech. E. 72. WV	Mech. E. 77. WV	E. E. 177. 501 E *E. E. 108
	1—4 Div. B	Chem. 183. 102 H *Mech. 110	E. E. 177. 202 E	†E. E. 103. 301 E E. E. 54 §Phys. 52	E. E. 175. 202 E Mech. E. 72. WV	E. E. 177. 501 E E. E. 176. 202 E	Mech. E. 77. WV *E. E. 108 **Mech. E. 60. WV

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *First half of term only. **Last half of term only. §As assigned. †2-3 P.M. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. Ph=Philosophy. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

Note: See Uniform Curriculum for First Class.

COURSE IN MECHANICAL ENGINEERING, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Mech. E. 11. 402 E Chem. 82. 309 H	Mech. E. 11-12 301 E	Mech. E. 59. 510 E Chem. 82. 309 H	Mech. E. 11-12 301 E	Mech. E. 59. 510 E Chem. 82. 309 H	Phys. 43, Lab. Div. A. 410 F Sh. Wk. 1, Lab. Div. B. 119 T
	10—11	Phys. 5. 301 F E. E. 2. 301 E	Phys. 5. 609 F, 713 J Met. 134. 306 M	Phys. 5. 301 F E. E. 2. 301 E	Phys. 5. 609 F, 713 J Met. 134. 306 M	Phys. 5. 301 F Mech. E. 12. 402 E	Phys. 44, Lab. Div. A. 410 F Sh. Wk. 12, Lab. Div. B. 29 T
	11—12	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 510, 609, 613 F, 713 J	
	1—2				Dft. 7. 302 E		
	1—4 Div. A	Sh. Wk. 1, Lab. 119 T Sh. Wk. 12, Lab. 29 T	Mech. E. 59. 510 E Sh. Wk. 12, Lab. 29 T	Mech. E. 35. 510 E Sh. Wk. 2, Lab. 31 T	Dft. 7. 601 E Mech. E. 12, Lab. WV	Sh. Wk. 1, Lab. 119 T Mech. E. 36. 510 E	
	1—4 Div. B	Phys. 43, Lab. 410 F Phys. 44, Lab.	Mech. E. 59. 510 E Mech. E. 36. 510 E	Sh. Wk. 1, Lab. 119 T Mech. E. 12, Lab. WV	Dft. 7. 601 E Sh. Wk. 2, Lab. 31 T	Mech. E. 35. 510 E Sh. Wk. 12, Lab. 29 T	
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	E. E. 101. 302 E E. E. 104. 302 E	Mech. E. 39. 301 U Mech. E. 32. 207 E	Mech. E. 39. 311 H E. E. 104. 302 E	E. E. 101. 302 E Mech. E. 64. 301 M	Mech. E. 39. 311 H E. E. 104. 302 E	Sh. Wk. 11, Lab. Div. A. 125 T Mech. E. 31, Lab. Div. B. WV Mech. E. 66. 301 M
	10—11	Mech. E. 31. 306 E C. E. 78. 302 E	Mech. E. 17. 301 M Mech. E. 18. 306 E	Mech. 105. 302 M C. E. 78. 302 E	Mech. E. 17. 301 M Mech. E. 64. 301 M	Mech. 105. 302 M Mech. E. 18. 306 E	Sh. Wk. 11, Lab. Div. A. 125 T Mech. E. 31, Lab. Div. B. WV Mech. E. 40. 301 H
	11—12	C. E. 53. 402 E, 301, 306 M Mech. E. 54. 301 H	C. E. 53. 402 E, 301, 306 M Mech. E. 70. 511 J	C. E. 53. 402 E, 301, 306 M Mech. E. 54. 301 H	C. E. 53. 402 E, 301, 306 M Mech. E. 70. 511 J	C. E. 53. 402 E, 301, 306 M *Mech. E. 60. 302 M §Met. 156. 302 M	Sh. Wk. 11, Lab. Div. A. 125 T Mech. E. 31, Lab. Div. B. WV Mech. E. 40. 301 H
	1—4 Div. A	†Sh. Wk. 11, Lab. 125 T *Mech. E. 60, Lab. WV **Met. 156. 508 M	E. E. 73, Lab. 201 E Mech. E. 40. 510 E	Mech. E. 31, Lab. WV Mech. E. 40. 510 E	Mech. E. 39. 510 E C. E. 54, Lab. 308 E	C. E. 53. 301 E Mech. E. 32, Lab. WV	**Met. 156. 508 M
	1—4 Div. B	E. E. 73, Lab. 201 E **Met. 156. 508 M	Sh. Wk. 11, Lab. 125 T Mech. E. 40. 510 E	Mech. E. 39. 510 E Mech. E. 40. 510 E	Sh. Wk. 11, Lab. 125 T Mech. E. 32, Lab. WV	C. E. 53. 301 E C. E. 54, Lab. 308 E	*Mech. E. 60, Lab. WV **Met. 156, 508
Fourth Class	9—10	Mech.E. 21. 301 E Mech. E. 50. 402 E	Mech. E. 45. 512 J Econ. 2. 511 J	Mech. E. 21. 301 E Mech. E. 50. 402 E	Mech. E. 45. 512 J Econ. 2. 511 J	Mech. E. 33. 402 E Law 2. 405 K	Mech. E. 21. 301 M Law 2. 405 K
	10—11	E. E. 103 A. 302E Mech. E. 26. 413 H	E. E. 105 A. 302 E Econ. 2. 511 J	Mech. E. 19. 302 E Mech. E. 26. 413 H	Mech. E. 25. 302 E Mech. E. 50. 306 E	Mech. E. 19. 302 E Mech. E. 52. 302 M	Mech. E. 21. 301 M Mech. E. 52. 511 J
	11—12	E. E. 103 A. 302 E E. E. 76. 402 E	E. E. 105 A. 302 E Mech. E. 20, 511 H	Mech. E. 19. 302 E	Mech. E. 25. 302 E Mech. E. 20. 511 H	Mech. E. 33. 306 E Mech. E. 20. 511 H	Mech. E. 45. 306 M Mech. E. 52. 511 J
	1—4 Div. A	Mech. E. 19. 506 E E. E. 76, Lab. 202 E	Mech. E. 21, Lab. WV Mech. E. 26. 506 E	Mech. E. 25. 506 E Mech. E. 20. 506 E	Mech. E. 33, Lab. WV Mech. E. 26. 506 E	Mech. E. 19. 506 E Mech. E. 20. 506 E	
	1—4 Dv. B	Mech. E. 19. 506 E Mech. E. 26. 506 E	Mech. E. 33, Lab. WV Mech. E. 26. 506 E	Mech. E. 25. 506 E Mech. E. 20. 506 E	Mech. E. 21, Lab. WV E. E. 76, Lab. 202 E	Mech. E. 19. 506 E Mech. E. 20. 506 E	

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *First half of term. §Second half of term. **Seven afternoons in second half of term. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

NOTE: See Uniform Curriculum for First Class

COURSE IN METALLURGICAL ENGINEERING, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. 301 F Chem. 82. 309 H	C. E. 23. 402 E Chem. 66. 301, 309 H	Phys. 5. 301 F Chem. 82. 309 H	Phys. 5. 510, 609 F E. E. 2. 302 E	Phys. 5. 301 F Chem. 82. 309 H	C. E. 23. 402 E Chem. 66. 301, 311 H
	10—11	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Phys. 5. 510, 609 F E. E. 2. 302 E
	11—12	Mineral. 7-8. 516 S	Geol. 5-6. 401 S	Mineral. 7-8. 516 S	Geol. 5-6. 401 S	Mineral. 7-8. 516 S	Geol. 5-6. 401 S
	1—2				Chem. 66. 301, 511 H	Dft. 7. 302 E	
	1—4	Phys. 43, Lab. 410 F Chem. 66, Lab. 504 H	C. E. 23. 402 E Chem. 66, Lab. 504 H	Mineral. 7, Lab. 106 S Chem. 66, Lab. 504 H	Phys. 43, Lab. 410 F Chem. 66, Lab. 504 H	Dft. 7. 601 E Mineral. 8, Lab. 106 S	
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	Met. 101, 111. 306 M E. E. 4. 301 E	Mech. E. 13-14. 301 E	Met. 101, 111. 306 M E. E. 4. 301 E	Mech. E. 13-14. 301 E	Met. 101, 111. 306 M E. E. 72. 301 E	C. E. 64. 301 U
	10—11	Met. 81. 306 M C. E. 78. 302 E	Geol. 105-106. 305 S	Mech. E. 13. 301 E C. E. 78. 302 E	Geol. 105-106. 305 S	Met. 81. 306 M Mech. E. 14. 301 M	Geol. 105-106. 305 S
	11—12	C. E. 53. 402 E, 301, 306 M Met. 122. 306 M	C. E. 53. 402 E, 301, 306 M Min'g 54. 302 M	C. E. 53. 402 E, 301, 306 M Met. 122. 306 M	C. E. 53. 402 E, 301, 306 M Min'g 54. 302 M	C. E. 53. 402 E, 301, 306 M Met. 122. 306 M	Min'g 54. 302 M
	1—4	Met. 81, Lab. 107 H Mech. E. 60, Lab. WV	Met. 81, Lab. 107 H	Met. 81, Lab. 107 H E. E. 72, Lab. 201 E	C. E. 53, Lab. 308 E Mineral. 6, Lab. 308 S Geol. 4, Lab. 402 S	C. E. 53. 301 E Mineral 6. Lab. 308 S Geol. 4, Lab. 402 S	C. E. 64
Fourth Class	9—10	Met. 151 Chem. 122. 413 H	Min'g 91. 302 M Met. 148. 301 M	Met. 151. 301 M Chem. 122. 413 H	Min'g 91. 302 M	Met. 175 Chem. 122. 413 H	Met. 131. 306 M Met. 138. 306 M
	10—11	Min'g 81. 302 M Min'g 94. 301 M	Mech. E. 17. 301 M Min'g 94. 301 M	Min'g 73. 301 M Met. 128. 306 M	Met. 141. 306 M Mech. E. 72. 302 M	Mech. E. 17. 402 E Met. 118. 306 M	E. E. 75. 613 F Mech. E. 72. 306 E
	11—12	Chem. 121. 413 H	Min'g 81. 302 M Mech. E. 76. 311 H	Chem. 121. 413 H Met. 158. 302 M	Min'g 81. 302 M	Chem. 121. 413 H	Min'g 81. 302 M Min'g 80. 301 M
	1—4	Met. 171, 77 Mech. E. 76, Lab. WV	Met. 171, 77, Lab. **Min'g 82, Lab. 201 M †Met. 172	Met. 171, 77, Lab. **Min'g 82, Lab. †Met. 172	Met. 171, 77, Lab. **Min'g 82, Lab. 201 M †Met. 172	Met. 171, 77, Lab. **Min'g 82, Lab. 201 M †Met. 172	E. E. 75, Lab. 202 E Mech. E. 72, Lab. WV

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *For students not having credit for this course. **Three weeks consecutive afternoons. †Afternoons not assigned to Mining 82. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. M=Mines. Ph=Philosophy. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

NOTE: See Uniform Curriculum for First Class.

COURSE IN MINING ENGINEERING, 1913-1914

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. 301 F Chem. 82. 309 H	C. E. 23. 402 E Chem. 66. 301, 309 H	Phys. 5. 301 F Chem. 82. 309 H	Phys. 5. 510, 609 F E. E. 2. 302 E	Phys. 5. 301 F Chem. 82. 309 H	C. E. 23. 402 E Chem. 66. 301, 311 H
	10—11	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	¶Math. 65. 202, 203, 213 Hm ¶¶Mech. 102. 609, 613 F, 613 Hm, 713 J	Phys. 5. 510, 609 F E. E. 2. 302 E
	11—12	Mineral. 1-2. 516 S	Geol. 5-6. 401 S	Mineral. 1-2. 516 S	Geol. 5-6. 401 S	Mineral. 1-2. 516 S	Geol. 5-6. 401 S
	1—2	Dft. 7. 402 E. Sec. I			Chem. 66. 301, 511 H	Dft. 7. 302 E. Sec. II	
	1—4	Dft. 7. 607 E. Sec. I Chem. 66, Lab. 504 H	C. E. 23. 302 E Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	Dft. 7. 607 E. Sec. II Mineral. 2. Lab. 106 S	
	4—5	Phys. Ed. B. 2 hrs. a week in sections.					
Third Class	9—10	Min'g 51. 302 M E. E. 4. 301 E	Mech. E. 13. 301 E Mech. E. 14. 301 E	Min'g 51. 302 M E. E. 4. 301 E	Mech. E. 13. 301 E Mech. E. 14. 301 E	Min'g 51. 302 M E. E. 72. 301 E	C. E. 64. 301 U
	10—11	Met. 81. Div. A. 306 M Mech.E. 13. Div. B. 301 M Min'g 52. 302 M	Geol. 105. 305 S Geol. 106. 305 S	Mech. E. 13. Div. A. 301 E Met. 81. Div. B. 306 M Min'g 52. 302 M	Geol. 105. 305 S Geol. 106. 305 S	Met. 81. 306 M Mech. E. 80. 511 H	Geol. 105. 305 S Geol. 106. 305 S
	11—12	C. E. 53. 402 E, 301, 306 M Mech.E. 14. Div. A. 302 M	C. E. 53. 402 E, 301, 306 M Min'g 54. 302 M	C. E. 53. 402 E, 301, 306 M Mech. E. 14. Div. B. 511 H	C. E. 53. 402 E, 301, 306 M Min'g 54. 302 M	C. E. 53. 402 E, 301, 306 M	Min'g 54. 302 M
	1—4 Div. A	Met. 81, Lab. 107 H Mech.E. 80, Lab. WV	Met. 81, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Met. 81, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	C. E. 53, Lab. 308 E E. E. 72, Lab.	C. E. 53. 301 E C. E. 54	§C. E. 53, Lab. 308 E C. E. 64, Lab.
	1—4 Div. B	C. E. 53. 301 E C. E. 54	§C. E. 53, Lab. 308 E E. E. 72, Lab. 201 E	C. E. 53, Lab. 308 E Mech. E. 80, Lab. WV	Met. 81, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Met. 81, Lab. 107 H †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Metal. 81, Lab. 107 H C. E. 64, Lab.
Fourth Class	9—10	Met. 101, 111. 306 M Min'g 72. 302 M	Min'g 91. 302 M Min'g 56. 302 M	Met. 101, 111. 306 M Min'g 72. 302 M	Min'g 91. 302 M Min'g 56. 302 M	Met. 101, 111. 306 M Min'g 72. 302 M	Met. 131. 306 M Min'g 56. 302 M
	10—11	Min'g 81. 302 M Min'g 94. 301 M	Mech. E. 17. 301 M Min'g 94. 301 M	Min'g 73. 301 M Geol. 110. 401 S	Met. 141. 306 M Mech. E. 74. 302 M	Mech. E. 17. 402 E Geol. 110. 401 S	E. E. 75. 613 F Mech. E. 74. 306 E
	11—12	Min'g 71. 302 M Met. 122. 306 M	Min'g 81. 302 M C. E. 76. 301 M	Min'g 71. 302 M Met. 122. 306 M	Min'g 81. 302 M C. E. 76. 301 M	Min'g 71. 302 M Met. 122. 306 M	Min'g 81. 302 M Min'g 80. 301 M
	1—4	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	E. E. 75. Sec. I. 202 E Min'g 75. Sec. II. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. Sec. I. 410 M E. E. 75, Lab. Sec. II. 202 E *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	*Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *Three weeks consecutive afternoons. **Ten consecutive afternoons. †During February and March. ‡During April and May. §As assigned. §§Afternoons not otherwise employed. A=Avery. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only. Geology 101, Fourth Year Elective, one Aft. per week.

GENERAL INFORMATION

REGARDING COLUMBIA UNIVERSITY

Columbia University was founded in 1754 as King's College. In 1784, after the Revolutionary War, King's College became, by act of the Legislature of the State of New York, Columbia College. The institution whose name was thus changed has become Columbia University.

Students in the Schools of Mines, Engineering and Chemistry may enjoy every advantage to be derived from the resources of the University. The University occupies thirty-six buildings, and its grounds cover thirty-five acres. The number of officers of instruction in 1912-13 was 869, and of resident students 8,944.

University Library The Library contains about 500,000 bound volumes, catalogued both by authors and by subjects.

It is open each week-day from 8.30 A.M. until 11 P.M. (in summer, 10 P.M.). All students and graduates have free access and may draw books for home use.

Physical Exercise The Gymnasium is open each week-day from 9.00 A.M. to 7 P.M.; and on Mondays, Thursday, and Saturdays until 10 P.M.

Every student is entitled to a physical examination by the Medical Director and to advice as to the kind and amount of exercise best adapted to his needs. For the Gymnasium fee see page 21.

The main exercising room is 35 feet high, semicircular in shape, and has an area of 16,000 square feet. It is well lighted and well ventilated. Above are the 10-lap running track, rooms for fencing, boxing, and handball, dressing-rooms with 1,804 steel lockers, and 32 shower-baths. Below the exercising room is the semicircular swimming pool, 100 feet by 50, and 4 to 10 feet deep, and shower-, needle-, and tub-baths.

A two-hour course in Physical Education is prescribed for all first and second year undergraduate students, arranged with a view to securing: first, health; second, strength, control, efficiency, and endurance; third, erect carriage.

There are on South Field a practice field for baseball, lacrosse, and football, a quarter mile running track, tennis courts, and the University Boat House is within easy reach.

Employment Committee The Employment Committee endeavors to give students who need it the opportunity to earn enough for partial or complete support, and to extend assistance in other ways. The office of the secretary of the Committee is in

THE GREEN AND UNION THEOLOGICAL SEMINARY FROM QUADRANGLE

Room 312, East Hall. Communications should be addressed to the Committee. Some of the openings available are: private tutoring, translating, addressing, copying of various sorts, teaching in evening schools, stenography. During the last ten years student earnings reported to the Committee have averaged about $100,000.00.

Preference is naturally given, in case of a choice of applicants, to those who, as strangers in New York, are not likely to hear of positions through other channels. No prospective student should come to Columbia expecting to depend entirely or even largely upon the assistance of the Committee, and every student should be prepared to meet at least the expenses of the first half-year—say $250.

The chiefs of clinic in the Medical School give advice without charge to students on the lists of the Committee.

There are also Appointment Committees whose duty it is to recommend graduates for teaching or other positions in colleges and universities and to assist competent men to obtain such positions.

Medical Attendance

The University Health and Sanitary Officer, Dr. McCastline, will have direct supervision of all matters affecting the health of the student body. All cases of communicable disease occurring in homes of students must be promptly reported to him.

As University physician Dr. McCastline will hold office hours daily in Earl Hall for consultation with the students.

For those who are without local family physicians there is a Medical Visitor (Dr. D. S. D. Jessup, 601 W. 113th Street) whose duties are to render medical assistance to such officers and students as may desire it, either at their homes or elsewhere, at a remuneration to be arranged between himself and individual patients.

Residence Halls

There are three University residence halls on South Field, with accommodations for 700 men; Hartley Hall, a memorial to the late Marcellus Hartley, Livingston Hall, named in memory of Robert R. Livingston, of the class of 1765, and Furnald Hall, provided for in the will of the late Francis P. Furnald in memory of his son, Royal Blackler Furnald, a member of the class of 1901. Each building is 137 feet by 60 and 10 stories high. They have electric light, steam heat, telephones, elevators and shower baths.

Hartley and Livingston each contain 300 rooms, the average size of the bedrooms being 8′ 0″ x 14′ 6″, and of the studies 10′ 0″ x 14′ 6″. Furnald contains 294 rooms, the average size of the bedrooms being 9′ 0″ x 14′ 9″, and of the studies 11′ 6″ x 13′ 6″. All the rooms have outside light and exposure, and the arrangement permits of flexibility in rent-

ing rooms in suites. There are also several double rooms. All ceilings are nine feet high. Each bedroom has a clothes closet and basin with hot and cold running water. The rooms are provided with heavy oak furniture of the Mission type. There are four shower baths on each floor. All the water used in the Halls is filtered.

The entrance for students to each Hall is from the campus, and leads directly into a large assembly room 60 feet square. This room runs up through two stories and has a large open fireplace opposite the entrance. It is furnished in heavy leather-covered oak. At one side of the main entrance is the office of the Hall, and on the other a reception room. In the basement is space for trunk storage. All baggage should be addressed to Hartley, Livingston, or Furnald Hall, Columbia University, and all charges should be prepaid.

University Commons

The University Commons, in University Hall, is operated under University management for the benefit of officers and students. The service is *à la carte*, or regular board may be secured for $6 a week.

Other Accommodations

Besides the dormitories and the Greek Letter Society club-houses there are many good boarding-houses and apartments near the University, a card-catalogue of which is kept at Earl Hall.

Public Lectures, etc.

In addition to the regular courses of instruction, numerous public lectures are given by the Institute of Arts and Sciences, ordinarily by persons of distinction who are not members of the teaching staff. The University maintains close relations with the other educational and public institutions of the city, and students enjoy unusual privileges at them. Students are also frequently given the opportunity to enjoy important dramatic and musical performances at a considerable reduced cost.

St. Paul's Chapel

St. Paul's Chapel, the gift of Olivia Egleston Phelps Stokes and Caroline Phelps Stokes, as a memorial to their parents, is in the form of a cross, the greatest length being 122 feet and the width at the transepts 77 feet. In all 1,050 sittings are provided. Of these, 120 are in the choir, which, as in the English cathedrals, may itself be used for a religious service at which the attendance is small.

Service. at which attendance is voluntary, is held every week-day except Saturday, at noon—the period from 12 to 12.20 being set apart by the University for religious exercises—and on Sunday afternoons at 4 P.M. There are also frequent organ recitals.

Special University services are held on the Wednesday preceding the Thanksgiving recess and on the first Wednesday of the second half year.

The chaplain and Mrs. Knox are at home to students (413 West 117th Street) each Sunday afternoon after the service.

Earl Hall

Earl Hall, the home of the religious, philanthropic, and social organizations and interests, is open to all students, without expense, from 8.30 A.M. to 10 P.M. daily, under the management of its Secretary, who is also Secretary of the University Young Men's Christian Association. Provision for the meetings of student organizations is made in the following order: Societies the purpose of which is (1) primarily religious; (2) primarily philanthropic; (3) primarily literary; and (4) miscellaneous student organizations. The building is also much used as a general student club house.

Student Organizations

The various student organizations, while self-governing, are subject to the following regulations: The schedules of public contests and performances must be approved by the University Committee on Student Organizations; budgets for expenditure are approved and checked by the Comptroller of Student Organizations; the University Committee on Athletics, consisting of three graduates, two students and two University officers, adopt and administer rules of eligibility not involving questions of scholarship and govern participation in inter-collegiate athletics. A pamphlet containing the full regulations, the constitution of the Athletic Association and the constitution of the Board of Student Representatives may be obtained from the Secretary of the University.

The Degree of A.M.

A college graduate who completes with marked distinction one of the regular professional courses may be recommended for the degree of Master of Arts if, while pursuing his professional course, he shall have taken additional work, under the Faculty of Pure Science, Philosophy or Political Science, to the extent of a major subject, and have presented a satisfactory essay upon an assigned topic. A detailed statement of the requirements for this degree and also for the Ph.D., with a list of subjects which may be offered, will be found in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science.* See also page 14.

Fellowships

For information as to the twelve University Fellowships, of the annual value of $650 each, and the several endowed fellowships open to qualified candidates for the degrees of Master of Arts and Doctor of Philosophy, see the *Announce-*

ment of the Faculties of Political Science, Philosophy and Pure Science, or the University Catalogue.

The following are of particular interest to students of Mines, Engineering and Chemistry, who are advised to familiarize themselves with the special regulations governing them:

The Tyndall Fellowship for the Encouragement of Research in Physics, endowed by Professor John Tyndall, and of an annual value of $648; the Barnard Fellowship for Encouraging Scientific Research, endowed by the bequest of the late President Barnard, annual value $412.50; the Ernest Kempton Adams Research Fellowship, founded by Mr. Edward Dean Adams in memory of his son, Ernest Kempton Adams, annual value $1,250; and the Samuel Anthony Goldschmidt Fellowship in Chemistry, of an annual value of $670.30.

Students

In 1912-13 the registration in the Schools of Mines, Engineering and Chemistry is as follows:

First-year class	180
Second-year class	161
Third-year class	145
Fourth-year class	159
Non-matriculated	23
Students from Columbia College	10
Total	678

Of students registered, 73 already held a college or technical degree, representing 37 institutions. In addition there are registered under the Faculty of Pure Science as candidates for the A.M. and Ph.D. degrees 17 students with some branch of Engineering (including 9 in Highway Engineering) and 56 with Chemistry as a major subject.

ALUMNI ORGANIZATIONS

The Alumni Association of the Schools of Science of Columbia University includes in its membership graduates of the Schools of Mines, Engineering and Chemistry. Associate membership is open to non-graduates, members of classes that have graduated.

Honorary membership is open to all persons eminent in Science who are or have been connected with any of the Schools of Science of Columbia University.

Its officers for 1912-13 are:

President, Benjamin B. Lawrence, E.M., '78.
Vice-President, Robert Van A. Norris, E.M., '85.
Treasurer, John S. Douglas, E.E., '90.
Secretary, Ralph E. Mayer, C.E., '79.
Post Office Substation 84, New York City.

Board of Managers

J. R. Brinley, C.E., '84.
W. I. Slichter, E.E., '96.
W. Newell, M.E., '07.
E. C. Kendall, Chem., '08.
W. M. Meserole, C.E., '81.
F. D. Dodge, Ph.B. (Chem.), '88.
D. M. Myers, M.E., '01.
G. E. Hutchinson, E.E., '09.

Delegates to the Alumni Council

Charles B. Going, Ph.B., '82
Edgar G. Barratt, C.E., '84.
Daniel E. Moran, C.E., '84.

A complete list of the Alumni, giving the addresses of each, and in the case of those who are members of the Association, a detailed record of their professional careers, is published and may be had on application to Professor R. E. Mayer, Secretary, Columbia University.

The Alumni Secretary will also be glad to put prospective students in communication with Alumni in different parts of the country. Such Alumni are often able to furnish information in a personal interview regarding the Schools of Mines, Engineering and Chemistry which inquirers at a distance could obtain in no other way.

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Local Association Secretaries

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ACADEMIC CALENDAR

1913-1914

1913

July 7. Monday. Fourteenth Summer Session opens.

Aug. 15. Friday. Fourteenth Summer Session closes.

Sept. 15. Monday. Entrance examinations and examinations for deficient and debarred students begin.

Sept. 17. Wednesday. Registration begins.

Sept. 23. Tuesday. Registration ceases for students previously matriculated. Later applications received only on payment of an additional fee of $5.

Sept. 24. Wednesday. First half-year, 160th year, begins. Registration ceases for students not previously matriculated. Later applications received only on payment of an additional fee of $5.

Sept. 25. Thursday. Lectures and recitations begin in courses.

Oct. 21. Tuesday. Stated meeting of University Council.

Nov. 4. Tuesday. Election Day, holiday.

Nov. 26. Wednesday. University service in St. Paul's Chapel.

Nov. 27. Thursday, to November 29, Saturday, inclusive, Thanksgiving holidays.

Dec. 16. Tuesday. Stated meeting of University Council.

Dec. 21. Sunday. Memorial service, St. Paul's Chapel.

Dec. 22. Monday, to

1914

Jan. 3. Saturday, inclusive, Christmas holidays.

Jan. 5. Monday. Last day for filing applications for entrance examinations.

Jan. 12. Monday. Mid-year entrance examinations begin.

Jan. 21. Wednesday. Mid-year examinations begin.

Feb. 3. Tuesday. First half-year ends.

Feb. 4. Wednesday. Second half-year begins. University service in St. Paul's Chapel. Registration ceases for students entering second half-year. Later applications received only on payment of an additional fee of $5. Scholars to report to the Registrar.

Feb. 12. Thursday. Alumni Day.

Feb. 17. Tuesday. Stated meeting of University Council.

Feb. 23. Monday. Washington's Birthday, holiday.

April 9. Thursday, to April 13, Monday, inclusive, Easter holidays.

April 21. Tuesday. Stated meeting of University Council.

May 1. Friday. Last day for filing applications for scholarships.
May 1. Friday. Deficiency examinations begin for fourth-year students only.
May 9. Saturday. Last day of instruction for fourth-year students.
May 13. Wednesday. Final examinations begin in subjects of the fourth year only.
May 16. Saturday. Last day of instruction for first-, second- and third-year students.
May 18. Monday. Final examinations begin.
May 30. Saturday. Memorial Day, holiday.
May 31. Sunday. Baccalaureate service.
June 1. Monday. Class Day.
June 3. Wednesday. Commencement Day.
June 10. Wednesday. Second half-year ends.
June 15. Monday. Entrance examinations begin.

July 6. Monday. Fifteenth Summer Session opens.
Aug. 15. Friday. Fifteenth Summer Session closes.

Sept. 14. Monday. Entrance examinations and examinations for deficient and debarred students begin.
Sept. 16. Wednesday. Registration begins.
Sept. 22. Tuesday. Registration ceases for students previously matriculated. Later applications received only on payment of an additional fee of $5.
Sept. 23. Wednesday. First half-year, 161st year, begins. Registration ceases for students not previously matriculated. Later applications received only on payment of an additional fee of $5.

The last day of the second half-year falls on the second Wednesday in June, and the academic year opens 37 weeks before that date. The second half-year opens on Wednesday, 19 weeks from the opening of the first half-year.

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Columbia University Bulletin of Information

SCHOOLS OF MINES, ENGINEERING AND CHEMISTRY

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CHEMISTRY

ANNOUNCEMENT

1914-1915

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These bulletins include:

1. The Report of the President and Treasurer to the Trustees.
2. The Catalogue of the University, issued in December, price 25 cents.
3. The Announcements of the several Colleges, Schools, and Divisions, issued in the Spring, and relating to the work of the next year. These are made as accurate as possible, but the right is reserved to make changes in detail as circumstances require. The current number of any of these Announcements will be sent without charge upon application to the Secretary of the University.

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FACULTY OF APPLIED SCIENCE

Officers of the Faculty

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ALEXANDER SMITH, PH.D...*Elected Delegate to the University Council*

ADAM LEROY JONES, PH.D.....*Secretary*

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Committee on Admissions

Professors JONES *(Chairman)*, MAYER, MORECROFT and THOMAS

The Faculty

NICHOLAS MURRAY BUTLER.....*President of the University*

A.B., Columbia, 1882; A.M., 1883; Ph.D., 1884; LL.D., Syracuse, 1898; Tulane, 1901; Johns Hopkins, Princeton, Yale, and University of Pennsylvania, 1902; Chicago, 1903; Manchester and St. Andrew's, 1905; Cambridge, 1907; Williams, 1908; Harvard and Dartmouth, 1909; D.Litt., Oxford, 1905; Jur.D. Breslau, 1911; Officer de la Légion d'Honneur, 1906, Commander, 1912; Order of the Red Eagle (Prussia), Commander, 1910; Member American Academy of Arts and Letters, 1911.

FREDERICK ARTHUR GOETZE.....*Dean of the Faculty*

M.Sc., Columbia, 1905.

HENRY S. MUNROE.....*Professor of Mining*

E.M., Columbia, 1869; Ph.D., 1876; Sc.D., 1904.

ALFRED J. MOSES.....*Professor of Mineralogy*

E.M., Columbia, 1882; Ph.D., 1890.

JAMES FURMAN KEMP.....*Professor of Geology*

A.B., Amherst, 1881; Sc.D., 1906; E.M., Columbia, 1884; LL.D., McGill, 1913; Member National Academy of Science.

ROBERT PEELE.....*Professor of Mining*

E.M., Columbia, 1883.

[1]FRANCIS B. CROCKER.....*Professor of Electrical Engineering*

E.M., Columbia, 1882; Ph.D., 1895.

MICHAEL IDVORSKY PUPIN.....*Professor of Electro-Mechanics and Director Phoenix Research Laboratories*

A.B., Columbia, 1883; Sc.D., 1904; Ph.D., Berlin, 1889; Member National Academy of Science.

WILLIAM H. BURR.....*Professor of Civil Engineering*

C.E., Rensselaer Polytechnic, 1872.

[2]THOMAS SCOTT FISKE.....*Professor of Mathematics*

A.B., Columbia, 1885; A.M., 1886; Ph.D., 1888.

[1]Absent on leave, 1914-15.
[2]Absent on leave, first half-year.

[2]HAROLD JACOBY.....*Rutherfurd Professor of Astronomy*
A.B., Columbia, 1885; Ph.D., 1895.

EARL B. LOVELL.....*Professor of Civil Engineering*
C.E., Cornell, 1891.

JAMES MACLAY.....*Professor of Mathematics*
C.E., Columbia, 1888; Ph.D., 1899.

MARSTON TAYLOR BOGERT.....*Professor of Organic Chemistry*
A.B., Columbia, 1890; Ph.B., 1894; LL.D., Clark, 1909.

J. LIVINGSTON RUTGERS MORGAN.....*Professor of Physical Chemistry*
B.S., Rutgers, 1892; A.M. and Ph.D., Leipzig, 1895.

AMADEUS W. GRABAU.....*Professor of Palæontology*
S.B., Massachusetts Institute of Technology, 1896; S.M., Harvard, 1898; S.D., 1900.

[3]RALPH EDWARD MAYER...*Associate Professor of Engineering Draughting*
C.E., Columbia, 1879.

CASSIUS JACKSON KEYSER.....*Adrain Professor of Mathematics*
B.S., Missouri, 1892; A.M., Columbia, 1896; Ph.D., 1901.

GEORGE L. MEYLAN.....*Associate Professor of Physical Education and Medical Director of the Gymnasium*
M.D., New York University, 1896; B.S., Harvard, 1902; A.M., Columbia, 1904.

LEA MCILVAINE LUQUER.....*Assistant Professor of Mineralogy*
C.E., Columbia, 1887; Ph.D., 1894.

HENRY CLAPP SHERMAN.....*Professor of Food Chemistry*
B.S., Maryland Agricultural College, 1893; Sc.D., 1913; A.M., Columbia, 1896; Ph.D., 1897.

ALBERT P. WILLS.....*Professor of Mathematical Physics*
B.E.E., Tufts, 1894; Sc.D., 1911; Ph.D., Clark, 1897.

SAMUEL A. TUCKER.....*Assistant Professor of Electro-Chemistry*
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CHARLES EDWARD LUCKE.....*Professor of Mechanical Engineering*
B.S., College of the City of New York, 1895; M.S., New York University, 1899; Ph.D., Columbia, 1902.

WALTER RAUTENSTRAUCH.....*Professor of Mechanical Engineering*
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[2]WILLIAM CAMPBELL.....*Associate Professor of Metallurgy*
B.Sc., Durham University, 1898; D.Sc., 1905; M.Sc., Royal School of Mines, 1903; Ph.D., Columbia, 1903; A.M., 1905.

EDWARD LAWRENCE KURTZ.....*Assistant Professor of Mining*
E.M., Columbia, 1893.

CARLTON CLARENCE CURTIS.....*Associate Professor of Botany*
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[2]ARTHUR L. WALKER.....*Professor of Metallurgy*
E.M., Columbia, 1883.

GEORGE BRAXTON PEGRAM.....*Associate Professor of Physics*
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BERGEN DAVIS.....*Associate Professor of Physics*
B.S., Rutgers, 1896; A.M., Columbia, 1900; Ph.D., 1901.

[2]Absent on leave, first half-year.
[3]Absent on leave, second half-year.

ADAM LEROY JONES.....*Chairman of Committee on Undergraduate Admissions and Secretary of the Faculty*
A.B., Williams, 1895; Ph.D., Columbia, 1898.

CHARLES H. BURNSIDE.....*Assistant Professor of Mechanics*
B.S., Columbia, 1898; A.M., 1899.

MORTON ARENDT.....*Assistant Professor of Electrical Engineering*
E.E., Columbia, 1898.

CHARLES P. BERKEY.....*Associate Professor of Geology*
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JOHN HAROLD MORECROFT..*Assistant Professor of Electrical Engineering*
E.E., Syracuse, 1904; B.S., 1907.

W. BENJAMIN FITE.....*Professor of Mathematics*
Ph.B., Cornell, 1892; Ph.D., 1901.

HERBERT E. HAWKES.....*Professor of Mathematics*
A.B., Yale, 1896; Ph.D., 1900.

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E.E., Columbia, 1896.

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SAMUEL OSGOOD MILLER.....*Assistant Professor of Drawing*
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EDWARD F. KERN.....*Assistant Professor of Metallurgy*
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HAL T. BEANS.....*Assistant Professor of Chemistry*
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CHARLES W. THOMAS..*Assistant Professor of Mechanical Engineering*
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LEONARD D. NORSWORTHY.....*Assistant Professor of Civil Engineering*
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Frederick V. D. Longacre.....*Associate in Mechanical Engineering*

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Lecturers

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JULIAN BLANCHARD.....*Lecturer in Physics*
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.....*Curator in Paleontology*

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EDGAR ALTENBURG.....*Assistant in Botany*
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EDWIN H. ARMSTRONG.....*Assistant in Electrical Engineering*
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GILBERT D. FISH.....*Assistant in Civil Engineering*
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FRANK J. MCMACKIN.....*Assistant in Mathematics*
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FREDERICK MILLER.....*Assistant in Civil Engineering*
C.E., Columbia, 1913.

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FREDERICK V. RAND.....*Assistant in Botany*
B.S., Vermont, 1908; M.S., 1911.

ROGER B. SAYLOR.....*Assistant in Physics*
A.B., Lebanon Valley College, 1911.

WARREN S. SMITH.....*Assistant in Geology*
B.S., Washington, 1912.

CLAYTON ULREY.....*Assistant in Physics*
B.S., Indiana, 1911; A.M., Maine, 1913.

FRANCIS M. VAN TUYL.....*Assistant in Paleontology*
A.B., Iowa, 1911; M.S., 1912.

DONALD B. KEYES.....*Laboratory Assistant in Chemistry*
B.S., New Hampshire State College, 1913.

Special Lecturers for 1913-1914

J. PARKE CHANNING, E.M.....*Miami Milling Practice*
Vice-Pres., Miami Copper Co.

HOWARD W. DU BOIS.....*"Salting" of Mines*
Consulting Engineer.

ADOLPH LEWISOHN.....*Business of Mining*
Mine Operator.

JAMES DOUGLAS, D.Sc.....*Metallurgy of Copper*

ARTHUR S. DWIGHT, E.M.....*Sintering of Fine Ore*
President, Dwight-Lloyd Met. Co.

GEORGE C. STONE, Ph.B.....*Metallurgy of Zinc*
Engineer, New Jersey Zinc Co.

ARTHUR P. DAY, Ph.D.....*Work of the Laboratory*
Director, Carnegie Geophysical Laboratory, Washington.

FRANK D. ADAMS, Ph.D.....*Physical Condition of the Earth's Interior*
Dean, Faculty of Applied Science, McGill University, Montreal.

F. W. PEEK, JR., M.S.....*High Voltage Transmission*
Consulting Engineering Department, General Electric Co.

A. L. POWELL, E.E..*Practical Illumination and Illumination Calculations*
General Electric Co.

A. L. BROE, E.E.....*Incandescent Lamps*
General Electric Co.

S. T. DODD, E.E.....*Self-propelled Railway Cars*
General Electric Co.

A. K. SELDEN, E.E.....*Interpole Machinery*
Crocker-Wheeler Co.

R. B. TREAT, E.E.....*Electric Motors in Steel Mills*
Crocker-Wheeler Co.

H. S. BLAKE, E.E.....*Arc Lamps*
General Electric Co.

F. P. COREY, E.E.....*Signal Engineering*
Union Switch and Signal Co.

FREDERICK A. HALSEY.....*Course on Shop Processes*
Editor Emeritus, "American Machinist."

FREDERICK V. D. LONGACRE.....*Course on Air Machinery*
Engineer, Ingersoll-Rand Co.

ARTHUR K. OHMES.....*Course on Heating and Ventilation*
Engineer, member of firm of Nygren, Tenney & Ohmes.

F. F. NICKEL.....*Course on Pumping Machinery*
Engineer, Henry R. Worthington Co.

H. L. GAUTT.....*Relation between Employer and Employee*
Consulting Engineer.

WM. T. PRICE, M.E.....*Gas Engine Development*
Sales Manager of De la Vergne Mach. Co.

THEO. MAYNZ, M.E.....*Bituminous Coal Stokers*
With Grieve Grate Co.

C. A. BROWNE, Ph.D.....*Sugar Production*
Chemist in Charge, New York Sugar Trade Laboratory, New York City.

W. D. HORNE, Ph.D.....*Sugar Refining*
Chemist, National Sugar Refining Company.

C. E. NORTH, M.D.....*Sanitary Milk Production*
Consulting Sanitarian, Secretary, New York Dairy Demonstration Company.

ROBERT SCHWARZ, B.S.....*Fermentation Industries*
Fermentation Expert.

DAVID WESSON, Ph.D.....*Edible Fats and Oils*
Manager Technical Department, Southern Cotton Oil Company.

P. A. LEVENE, Ph.D., M.D.....*Biological Utilization of Sugars*
Rockefeller Institute for Medical Research.

H. E. HOWE, B.S., Chemist.....*The Relation of Chemical Nature to Physical Properties of Glass*
Chief Chemist at Bausch & Lomb Optical Co., Rochester, N. Y.

ROBT. RIDGWAYS.....*Present Subway Construction in New York*
Chief Engineer of Construction, Public Service Commission.

J. WALDO SMITH, C.E.....*The Catskill Extension of the Public Water Supply of New York City*
Chief Engineer, Board of Water Supply.

J. A. O'ROURKE.....*Subway Excavation*
Contractor, New York City.

GEORGE C. WHIPPLE, S.B.....*Sanitary Engineering*
Member, firm of Hazen & Whipple, Consulting Engineers; Professor of Sanitary Engineering, Harvard University.

NELSON P. LEWIS, C.E.....*Financing Municipal Improvements*
Chief Engineer, Board of Estimate and Apportionment, New York City.

GEORGE W. FULLER, S.B.....*Sewage Disposal*
Consulting Engineer, New York City.

JOHN A. BENSEL, M.E..*Relative Cost of Transportation by Waterways, Railways and Highways*
New York State Engineer, Albany, N. Y.

WILLIAM H. CONNELL..*Organization and Methods of Street Cleaning Departments*
Chief, Bureau of Highways and Street Cleaning, Philadelphia, Pa.

C. A. Crane.....*Applications of Contract Law to Highway Construction Problems*
Secretary, The General Contractors Association, New York City.

W. W. Crosby, C.E., D.Sc.....*The Value of Cost Data in Highway Engineering*
Chief Engineer, Maryland Geological and Economic Survey, and Consulting Engineer.

Charles Henry Davis, C.E.....*National Highways*
President, National Highways Association, South Yarmouth, Mass.

John H. Delaney.....*The Fundamental Elements of Finance*
Commissioner, New York State Department of Efficiency and Economy, Albany, N. Y.

A. W. Dow, Ph.B..*Details of Construction of Wood Block Pavements*
Chemical and consulting Paving Engineer, New York City.

H. W. Durham, C.E.....*The Highways of Panama*
Chief Engineer of Highways, Borough of Manhattan, New York City.

C. N. Forrest.....*The Essential Chemical and Physical Properties of Creosoting Oils for Wood Blocks*
Chief Chemist, New York Testing Laboratory, Maurer, N. J.

Walter H. Fulweiler, B.Sc.....*The Manufacture of Refined Water Gas Tar*
Chief Chemist, United Gas Improvement Company, Philadelphia, Pa.

Frank B. Gilbreth....*The Principles of Efficiency Engineering as Applied to Highway Engineering*
Consulting Engineer, New York City.

George P. Hemstreet.....*The Manufacture of Asphalt Blocks*
Superintendent, The Hastings Pavement Company, Hastings-on-Hudson, N. Y.

Samuel Hill, A.B.....*Highways of the Northwest*
President, American Road Builders Association, Seattle, Wash.

D. L. Hough, Ph.B.....*Highway Specifications from the Standpoint of the Contractor*
President, The United Engineering and Contracting Company, New York City.

J. W. Howard, B.L., C.E., E.M..*European Rock Asphalts, Obtaining, Preparation and Uses*
Consulting Engineer, New York City.

Arthur N. Johnson, S.B....*Economics of Highway Engineering in the Middle West*
State Highway Engineer, Springfield, Ill.

William H. Kershaw.....*Commercial Mining, Transportation and Storage of Asphaltic Oils*
Manager, Paving and Roads Division, The Texas Company, New York City.

Nelson P. Lewis, A.B., C.E.....*The Administration of Municipal Public Works*
Chief Engineer, Board of Estimate and Apportionment, New York City.

Harold Parker....*Responsibility of Contractors for Construction of Roads and Pavements Designed by Engineers*
First Vice-President, Hassam Paving Company, Worcester, Mass.

PAUL D. SARGENT, B.C.E..*Gravel and Its Use in Highway Construction*
Chief Engineer, State Highway Commission, Augusta, Me.

PHILIP P. SHARPLES, A.B.....*The Manufacture of Refined Coal Tar*
Chief Chemist, Barrett Manufacturing Company, Boston, Mass.

FRANCIS P. SMITH, Ph.B..*Plant, Highway and Laboratory Inspection of Bituminous Materials*
Chemical and Consulting Paving Engineer, New York City.

ALBERT SOMMER, D.Ing.....*The Mining and Refining of Asphaltic Oils*
Consulting Chemist, New York City.

GEORGE W. TILLSON, C.E..Details of Construction of Car Tracks in *City Pavements*
Consulting Engineer to the President of the Borough of Brooklyn, New York City.

University Officers of Administration

FRANK DIEHL FACKENTHAL, A.B.....*Secretary of the University*
FRANK A. DICKEY, A.B.....*Registrar of the University*
CHARLES S. DANIELSON.....*Bursar*
HENRY L. NORRIS, M.E.....*Superintendent of Buildings and Grounds*
MALCOLM M. ROY, A.B.....*Secretary of Appointments*

Chaplain of the University
REV. RAYMOND C. KNOX, B.D.

Medical Director of the Gymnasium
GEORGE L. MEYLAN, M.D.

Secretary of Earl Hall
CLIFFORD K. BROWN, A.B.

University Medical Officer
WILLIAM H. MCCASTLINE, M.D.

INTRODUCTORY

The first step for the foundation of a Faculty of Applied Science was taken in 1864, when the Trustees approved the creation of a School of Mines, in which courses were later established in civil engineering, chemistry, and metallurgy. The growth of these courses made it seem desirable to adopt some more comprehensive name than the historic title "School of Mines," so that in 1896 the Schools of Engineering and Chemistry were set off from the School of Mines, the three schools remaining, however, under the jurisdiction of a single faculty:

1. The School of Mines, with four-year courses leading to the degrees of Engineer of Mines and of Metallurgical Engineer.

2. The School of Engineering, with four-year courses in Civil Engineering, Sanitary Engineering, Electrical Engineering, and Mechanical Engineering, leading to the degrees of Civil Engineer, Electrical Engineer, and Mechanical Engineer respectively.

3. The School of Chemistry, with four-year courses, leading to the degrees of Chemist and Chemical Engineer.

The courses are intended to meet the requirements of the several professions indicated; and many of them permit a certain amount of specialization, particularly in the fourth year. The work in the School of Mines is so arranged that the student can emphasize the engineering, the metallurgical, or the geological side of his profession.

Candidates for a professional degree who have some special end in view are occasionally permitted to vary the regular course by substituting other courses offered under the Faculty of Applied Science.

In the regular Summer Session held at the University in July and August of each year many courses of assistance to engineering students are offered. The *Announcement of the Summer Session* will be sent upon application to the Secretary of the University.

NEW REQUIREMENTS FOR ADMISSION

For fuller statement see pages 15-16

Beginning in September, 1915, the professional work in Mines, Engineering and Chemistry established at Columbia just fifty years previous will be placed upon a graduate basis and will require of candidates for admission not only a broad foundation in Mathematics, Chemistry and Physics, but training in English, Modern Languages and in the fields of History and Political Science.

The purpose of this important change is to offer better and broader training for students of engineering, and to place the instruction in these professional subjects upon the same university plane as the

instruction in law and medicine. The recent rapid development of engineering practice, the wider social and public recognition now given to the engineering profession and the frequent demands that men in executive and administrative posts shall have had an engineering education make it imperative that the engineer of the future shall be a broadly educated professional man and not merely a technical expert. In order to insure this it is necessary that the future engineer shall widen his intellectual outlook by continuing his general education considerably beyond the limits of the ordinary high school course. At the present time, even before the proposed new system is in operation, one hundred and fifty students in Columbia University are taking advantage of the existing opportunity to combine a college and engineering course.

Students who are looking forward to entering upon any branch of the profession of engineering are invited to address the Secretary of Columbia University in order that they may obtain the fullest possible information regarding conditions of admission, the program of studies and the cost of university residence, including tuition fees, room rent and other necessary expenses.

ADMISSION IN 1914

Advice for Candidates with Collegiate or Technical Training Contemplating Entering in 1914

Students at other colleges and technical schools who contemplate entering Columbia University in 1914 as candidates for the professional degrees in Mining, Metallurgy, Engineering and Chemistry must submit credentials showing that they have had the equivalent of the uniform first year in the Schools of Mines, Engineering and Chemistry as outlined on page 15, in which case they will be admitted to the second class as candidates for degrees in 1917.

If the curriculum followed elsewhere does not exactly satisfy the above requirement, opportunity will be offered in the Summer Session of Columbia University during July and August to receive instruction in any of the subjects required for admission for which provision may not be made in the college which they attended.

If the candidate will send to the Secretary of the University a marked catalogue showing the courses he will have completed by June, 1914, and also a statement from the registrar of the college which he is attending showing his standing in his courses, he will be advised of what credits will be assigned to him and of how long approximately it will take him to complete a course leading to an engineering degree.

PREPARATORY PROGRAM OF STUDIES

Three Years' Course Leading to the Degree of Bachelor of Science

In order to make adequate provision within the University for students who desire to prepare themselves in three years of college residence for these courses the following program of studies leading to the degree of Bachelor of Science has been authorized by joint action of the Faculties of Columbia College and Applied Science.

The unit of credit in Columbia College is the "point," each point representing either one hour classroom work for a half-year, two hours laboratory, or three hours drafting or shop work. To receive the bachelor's degree 124 points must be made, including all prescribed subjects.

The following schedule is made out for the student who offers what has proved to be the normal entrance requirements for the B.S. degree, i.e., who includes among the 14½ units prescribed for admission, Trigonometry and Solid Geometry, the elementary and intermediate requirements in one modern language, Physics, Chemistry and Drawing, besides English and elementary mathematics. For students who do not complete all of these subjects in school and who cannot complete them in the Summer Session previous to their entrance or at the close of the first year, special programs will have to be arranged, cutting necessarily into the opportunities for elective work.

Prescribed

FIRST YEAR

FIRST HALF		SECOND HALF	
Advanced Algebra (Math. 1)	3	Analytical Geometry (Math. 4)	3
English Composition (Engl. **A1**)	3	Chemistry, Gen'l {2 Lect. 6 Lab.}	5
Principles of Science (Philosophy **A1**)	3	English Composition (Engl. **A2**)	3
Modern Language based on Intermediate Entr. requirement	3	Principles of Science (Philosophy **A2**)	3
Shop Work (2 Aft.)	2	Modern Language (continued)	3
Physical Education **A1**	2	Physical Education **A2**	2
Additional work in Mod. Language, Philosophy or English	4	Total points.....	39

If Drawing has not been offered for entrance, a one point course in Drafting may be added.

Second Year

First Half		Second Half	
Calculus (Math. 15)	4	Calculus (Math. 16)	4
Chemistry, General (2 Lect., 6 Lab.)	5	Chemistry, Qualitative (2 Lect., 6 Lab.)	5
English Literature (English B3)	3	Physics (3 Lect., 3 Rec.)	6
Epochs of History (Hist. A1)	3	Epochs of History (Hist. A2)	3
Drafting (2 afternoons)	2	Drafting (2 afternoons)	2
Descriptive Geometry (Drafting (3)	3	Total points.....	40

Summer shop work—4 weeks—is prescribed for admission to the Schools of Mines, Engineering and Chemistry, but is not counted in points toward a bachelor's degree.

Third Year

First Half		Second Half	
Physics (3 Lect., 3 Rec., 1 afternoon Lab.)	7½	Physics (same)	7½
Calculus	4	Statics (Mechanics 2)	2
Chemistry, Qualitative (2 Lect., 6 Lab.)	5	Economics	3
Government and Industry	3	Mineralogy (2 Lect. 1 afternoon)	3
		Surveying (Civil Eng. 2)	2
		Total points.....	37

A Summer Course in Surveying of five weeks to be taken at the close of this year is prescribed for admission to the Schools of Mines, Engineering and Chemistry.

Elective

To make up the requirement of 124 points for the degree of B.S., ten additional points must be made either by extra credit for high standing, by work in Summer Sessions or by free election during the program; such election may be made at the student's option from among the courses in which he can satisfy the pre-requisites, subject to the approval of the Committee on Instruction.

COURSES PRESCRIBED FOR CANDIDATES FOR THE B.S.

Information regarding *elective* courses may be found in the Announcement of Columbia College for 1914-15.

Chemistry

General Course. This course forms a sequel to entrance Chemistry. It continues the study of general chemistry, with particular reference to giving a greater knowledge of descriptive chemistry and a more advanced and systematic discussion of the general principles and their

applications. It affords also the necessary preparation for qualitative analysis.

Qualitative Analysis. This course deals with the theory and practice of inorganic qualitative analysis, based upon the principles of modern chemistry.

Drafting

Drafting.

(a) Elements of mechanical drafting—Use of instruments; plane problems; free hand lettering; dimensioning; *(b)* Projections—Orthographic projection; intersections; developments; problems in descriptive geometry; isometric projection; cabinet projection; *(c)* Machine drafting—Conventional signs for materials of construction; sketching of machine details. Working drawings; tracings; blue printing; *(d)* Topography—Conventional signs; hill shading; mapping.

Descriptive Geometry.

Problems on point, line, and plane; classification of surfaces; tangent planes to single curved surfaces and surfaces of revolutions; intersections; developments; warped surfaces.

English

A. Review of principles of English Composition, developed in individual conferences. Assigned weekly readings and class-room discussion.

B. A course of intensive study of representative English authors. Reports on reading and class-room work at fortnightly intervals.

History, Economics and Politics

History A.—Modern History. A fundamental course in the politics and society of modern times; treats of the commercial revolution of the sixteenth century and of the industrial revolution of the eighteenth and nineteenth centuries; and lays special emphasis upon current national and international problems in Europe and in the United States.

Economics. Lectures, reading and text-book discussion. In this course the fundamental principles of economics are studied with particular reference to their application to current economic and social problems in the United States, and with special regard to the needs of students in engineering.

Government and Industry. A course designed for students who wish to gain an insight into their duties and responsibilities as citizens and knowledge as to the relations of government and industry.

Mathematics

Algebra. This course deals with such topics as premutations and combinations, determinants, complex numbers, the theory of equations, and partial fractions.

Analytical Geometry. This course deals with such topics as coordinate systems, transformations, loci and their equations, with particular reference to the straight line and conic sections, and the elements of three-dimensional geometry.

Calculus. First course, in differential and integral calculus.

Calculus. A continuation of the above, with further applications to geometry, physics, and mechanics, and an introduction to differential equations.

Mineralogy

General Mineralogy. The character and laws of Minerals and Crystals. The sight recognition and determination of the common rock-forming minerals and the great ores.

Modern Languages

French. Practice in speaking and writing French. French 3 is based on French history and French 4 on scientific French. Both courses are conducted entirely in French.

The work consists of summing up notes taken in the class room, making oral reports on assigned reading, and writing weekly French compositions based on the work done during the week.

German. A special course in German organized in September, 1913, based on the intermediate entrance requirements.

Spanish. By special permission a student with good linguistic training may offer Spanish instead of French or German.

Philosophy

Philosophy A. The Principles of Science. The first half of this course is devoted to a study of the elements of logic inductive and deductive, with practical exercises in the application of logical principles. The second half considers the application of these principles in scientific investigation and includes a careful examination of leading scientific concepts, such as matter, energy, cause, law, purpose, evolution, etc.

Physical Education

Physical Education A. Elementary graded gymnastics, athletics, swimming, and lectures on personal hygiene. The work is conducted on South Field during the first five weeks and after that time in the Gymnasium. The lectures are given during January.

Physics and Mechanics

Physics. General Physics: Mechanics, Wave-Motion and Heat.

Mechanics: Newton's laws of motion; accelerated linear and angular motions; dimensions; systems of weights and measures; energy, work, power; transformations of energy; conservation of energy; curvilinear motion with applications; gravitation; linear and angular simple harmonic motion; pendulum; wave-motion, including a general discussion of reflection, refraction, interference, resonance; elements of hydrostatics.

Physics. Heat and Light

Heat: Nature of heat; expansion; thermometry and pyrometry; carolimetry; specific heat; mechanical equivalent of heat; change of state; saturated vapors and hygrometry; continuity of state and liquefaction of gases; conduction; convection; radiation.

Light: General discussion of the wave-theory; reflection; refraction; total reflection; index of refraction and its measurement; lenses; dispersion; spherical and chromatic aberration; optical instruments; photometry, color; luminescence; spectrum analysis; problems of illumination; polarization of light.

Physics. Electricity.

Phenomena of electrostatics; capacity and condensers; electrometers; current electricity and methods of production; Ohm's law with applications; Joule's law; measurement of e. m. f., current, resistance, power and capacity; thermo-electricity; magnetic action of currents with applications; electrical units, electro-magnetic induction, inductance.

Statics. Coplanar statics is treated by both algebraic and graphical methods.

Physics. Physical Laboratory.

This course consists of quantitative experiments with reports in mechanics, light, heat, electricity and magnetism; methods of computation, plotting, and the precision of measurements are discussed in connection with the experiments.

Shop Work

Shop Work. Wood-turning and Pattern-making. Forging and Foundry Practice and Machine Shop.

Surveying

Theory of Surveying. Methods of measuring angles and distances. Cumulative and compensating errors, and corrections to be applied. Limits of precision. Use, care, and adjustment of the engineer's transit, level, and compass. Magnetic declination and variation. Local attraction. Relocation of old lines by compass bearings. Erroneous standards. Surplus and deficiency. Significance of monuments. Traverses; computations of area and error of closure. Laying out and dividing up

land. System of public land surveys. Topographic surveys; transit stadia and plane table methods. Triangulation. City surveying, subdivision and resurveys. Interpretation of deed descriptions. Textbook: Tracy's *Plane Surveying.*

Admission to Special Courses of Study

Graduates of these Schools, and other institutions of equal grade, may pursue any subjects taught in the schools for which they are qualified.

Persons of mature age who are not graduates, but who show special qualifications, are sometimes permitted to pursue special courses of study, but this permission is not given to others.

Persons who wish merely to pursue elementary subjects are not received as non-matriculated students.

Non-matriculated students will be held to the observance of the same regulations as to attendance, examination and proficiency as matriculated students.

ADVICE TO STUDENTS

Each student is on entrance assigned to an officer of instruction, who acts as his academic adviser. The adviser is kept informed as to the attendance and standing of all such students in their academic work and as to the extent and character of their participation in extracurricular activities, and he advises students on all these and other matters that concern them as students.

Reports of standing are sent to the student, his parent or guardian, his adviser and to the Dean every five weeks for students in the second class and at the end of each term for students in the third and fourth classes.

A students who has not been assigned to an adviser may apply to the Dean for such assignment.

REGISTRATION

Before attending any University exercises each student must register, *i. e.*, must present himself in person to furnish the information necessary for the University records and to file a statement of the courses he is authorized to pursue (for the matriculation or registration fee, payable but once, see below).

The office of the Registrar, 201 East Hall, will be open for registration from Wednesday, September 16, to Tuesday, September 22, 1914. New students may register also on September 23. Credit for attendance will date from September 24.

COLUMBIA UNIVERSITY FROM THE WEST

Students prevented, through no fault of their own, from completing their registration in due time, should file a provisional registration blank.

Registration at a later date is permitted only to candidates who obtain the written consent of the Dean, satisfactory cause for the delay having been shown. (For the fee for late registration see below.)

Students holding scholarships are required to register not later than the date specified in the University calendar; failure to do so may be considered as vacating the scholarship.

Honorable Dismissal

In case of withdrawal during the academic year, students are required to file a notice thereof with the Registrar, on a blank form provided for the purpose. An honorable dismissal is granted by the Dean to any student in good standing over twenty-one who may desire to withdraw, and, with the written assent of his parent or guardian, to a student under that age. Applications for leave of absence should be addressed to the Dean.

FEES

The President is under instructions to withdraw the privileges of any student delinquent in payment after the second Wednesday of each half-year. All regulations as to fees are subject to change by the Trustees at their discretion.

For Matriculation or Registration: Required of all students on entrance, payable but once..... $5
For late Registration (see above)..... 5

For Changes of Registration after the second Saturday of any half-year, for any course or courses added or dropped at any one time..... 1

For Tuition in the Schools of Mines, Engineering and Chemistry, payable at the beginning of each half-year: For matriculated students for each half-year..... 125
For non-matriculated students, $7.50 per half-year for each hour of attendance upon lectures and recitations per week; with additional charges for laboratory work up to $25 per half-year when the number of hours weekly of such work does not exceed nine, and of $40 per half-year when the number of hours weekly exceeds nine; the whole not to exceed $125 per half-year.

For the use of the Gymnasium: Required of all students who do not hold an academic degree; optional for students holding such a degree..... 7

For examinations, payable in each case before the examination:

For a deficiency examination or series of deficiency examinations held in the week preceding the opening of the first half-year, for each course $5, with a maximum of..... 25

For a deficiency examination at any other time than in the period designated above, whether taken at the conclusion of a course repeated by the student in addition to his normal schedule, or without such repetition, for each course[1]..... 5

For special examinations at unusual times:

For removal of deficiencies in course, for each course..... 5

For any professional degree, payable prior to filing of application[2]..... 25

Summer Courses in Surveying, Mining and Geodesy

Laboratory fees are required for summer courses in surveying as follows: Civil Engineering, Course 15S, $20, or $5 per survey; courses 25S and 27S, $20, or $4 per survey; courses 26S, 26aS and 71S, $10.

All students not registered as regular students in the Schools of Mines, Engineering and Chemistry at Columbia University will be charged the tuition fees for each course or part of a course, as follows:— Course 15S, $15, or $4 per survey; courses 25S and 27S, $15, or $3 per survey; courses 26S, 26aS, 28S and 71S, $10. In the case of students registered in the Schools of Mines, Engineering and Chemistry, the tuition fee for the scheduled summer courses is included in the fee charged for tuition at the University for the year preceding.

Students entering with advanced standing, but deficient in surveying field work, will be charged tuition fees, and also students taking work at Camp in advance of the specified time. In the latter case, however, the fee so paid will be deducted from the regular tuition fee paid at the University for the year in which the work is regularly scheduled.

Regular students in the Schools of Mines, Engineering and Chemistry who fail to take the prescribed Camp courses in Surveying at the time assigned for this work will be charged a postponement fee of $10 for each course except C.E. 26S and 26aS, for which the charge will be $5. Students failing to complete these courses during one session of the school will be charged an additional fee of $2.50 for each survey.

These postponement fees may be remitted in whole or in part, but only for reasons of weight, and upon written application to the Director of the Summer Session. Thus students who are prevented from taking the courses at the time assigned, through serious illness,

[1] This applies to every course in which the student has already received a mark other than passing, whether such mark was reported as a failure, or merely as incomplete.

[2] Refunded to unsuccessful candidates upon application to the Registrar not later than June 20 next ensuing.

conflicts with other courses, or the necessity of postponing the work for financial reasons, may be excused from payment of these fees. In every case, application must be made to the Director of the Summer Session before May 2 of the year in which the work should be taken. Except in cases of serious illness, applications submitted later than this date will not be considered. Students whose applications have been approved will be given a statement, which must be presented to the Bursar at the time of payment of fees, and afterwards submitted to the Resident Director at Camp when reporting for the course.

For the summer course in Geodesy a laboratory fee of $25 is charged. The tuition fee operative as above described for courses in surveying is $15.

Candidates for admission to advanced standing who attend the Summer Course in Practical Mining are required to pay therefor a fee of $50.

DEPOSITS

Summer Courses in Surveying

Every student before starting for Camp, and at the same time the fees for the summer session in surveying are paid, shall make a deposit at the Bursar's office at Columbia University to meet Camp expenses, viz., board, laundry, charges for drawing material, notebooks, etc.; also to cover any damage to, breakage, or loss of instruments or Camp equipment, and transportation of self and baggage from the station to and from the Camp. The Bursar's receipt for said deposit shall be presented to the professor in charge of the summer session upon the arrival of the student in Camp.

The amount of the deposit varies with the course or the number of courses taken and is as specified below. Students intending to take two or more courses shall deposit an amount equal to the sum total of the deposits herein specified for the respective courses. A check for the balance of the deposit which shall remain to the credit of the student after his withdrawal from the session will be given to him payable upon application to the Bursar of Columbia University. In case the total charges exceed the deposit the student will be subject to an additional assessment.

The deposit for C.E. **15S** shall be $50; for C.E. **25S**, $50; for C.E. **26S** and **26aS**, $25; for C.E. **27S**, $50; for C.E. **28S**, $35; for C.E. **71S**, $35; and for Geodesy **107**, $30.

The deposit for any one *survey* of Course 15, 25, or 27 shall be $15.

Apparatus, Supplies and Keys to Desks and Lockers

A deposit for the use of lockers, keys, apparatus, material, and the like, ranging from $1 to $40, is required of students in Mines, Engineering and Chemistry. At the end of the academic year each student

will be credited with those articles which he returns in good order, and the value of those he has injured or broken will be deducted from his deposit. Details may be obtained from the Bursar.

Residence Halls and University Commons

(See page 151)

Employment Committee

(See page 150)

Comparative Statement of Students' Probable Expenses for the Academic Year

	Low	Average	Liberal
Matriculation	$ 5	$ 5	$ 5
Gymnasium	7	7	7
Tuition	250	250	250
Books	20	40	60 up
Drafting material	2	10	15 "
Chemical apparatus	25	35	45 "
Room (37 weeks)	90	129	180 "
Board (37 weeks)	160	180	205 "
Clothes and laundry	45	100	175 "
College incidentals	2	15	25 "
Other expenses	10	25	75 "
Summer Courses in Surveying			
Laboratory	25	25	25
Travelling	5	5	5 up
Board (5 weeks)	35	35	35 "
	$681	$861	$1107

The expense for summer courses in surveying applies to all curriculums during the first summer only; for Mining and Metallurgical Engineering students during two summers; for Civil and Sanitary Engineers three summers.

RULES GOVERNING STUDENTS

1. A student cannot be a candidate for more than one professional degree at the same time.

2. A candidate for a degree must comply with all requirements in force at the time said degree is conferred.

3. A student will be permitted to substitute one subject for another provided he obtains the consent of the Dean, the heads of departments concerned and the head of the department giving the technical instruction leading to the degree.

4. A student absent from more than one-tenth of the required exercises will be debarred from examination in that subject. No student shall be exempt from this regulation except by action of the Committee on Instruction.

5. After examinations have been held, officers shall report to the Registrar the standing of all students who have attended their courses, in terms of the letters "A," "B," "C," "D" and "F." "A," "B" and "C" to be passing grades, "D" signifying a deficiency removable by re-examination, and "F" a complete failure. Reports of standing will be sent to Second-year students every five weeks, and to Third- and Fourth-year students at the end of each term. Copies of all reports are at the same time sent to the Dean, to the Faculty adviser and, in the case of Second-year students, to the parent or guardian. They will be sent to the parent or guardian of Third- and Fourth-year students only on request.

6. Regular examinations shall be held at the end of the first half-year, and at the end of the second half-year in all subjects offered during those respective periods. An examination may be held at the completion of any subject which does not extend throughout the given half-year.

7. Special examinations for students deficient at regular examinations shall be held during the two weeks in September preceding the opening of the next following academic year; and for members of the fourth class in subjects belonging to that year only, during the first week in May.

Students who have been debarred and students who have received a grade of "F," either during the regular term or in the Summer Session, are excluded from such examinations in accordance with the terms of the following rule:

Any student who shall have been debarred from or shall have received a grade of "F" in any midyear or final examination or in the Summer Session in any subject shall not be allowed to take a deficiency or make-up examination in said subject until he shall have repeated said course in class.

8. Failure to pass a Summer Session course, credit for which would be accepted as equivalent to a regular undergraduate course in the Schools of Mines, Engineering and Chemistry, shall be counted, in case a student registers for said course, as one of the three failures referred to in Rule 10.

9. The fee for special examinations is $5 for each course, which must be paid when the application is made. For special examinations in the September series the maximum fee is $25.

10. A student failing to pass in any subject at the regular examinations must present himself for special examination as provided under Rule 7.

Failing to pass the second examination, he must repeat the subject with the next class. Failing a third time to pass a satisfactory examination he may be dropped from the roll of the School.

11. Absence from any regular or special examination provided for in Rules 7 and 8 shall count as a failure unless excused by the Dean for reasons of weight.

12. No student having an entrance deficiency shall be permitted to register for any subject of the second, third or fourth year without the written consent of the Dean, and no student shall be permitted to register for any subject the prerequisites for which have not been satisfied by him unless the Dean, for reasons of weight, grants him special permission.

13. Any student who shall have passed a satisfactory examination in Columbia College in any subject forming a part of one of the professional courses in the Schools of Mines, Engineering and Chemistry will not be required to pursue that subject a second time.

14. During vacations following the close of each year, memoirs on assigned subjects must be prepared by the students in the courses of Mining, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, and Chemistry. The time specified for the completion and handing in of memoirs will be as stated in the respective departmental announcements.

A student failing to hand in his memoir, drawings or other summer work at the time specified by the department in which he is registered shall be considered to have failed; to have his work received later, he will be obliged to pay a fee of $5, as for a special examination.

15. By permission of the Dean, and concurrence of the heads of departments concerned, a student may attend subjects not required for his degree, provided such attendance does not interfere with his regular work. He must fulfill all the requirements exacted from regular students in such course.

Application for each special examination, except as provided below, must be filed at the office of the Registrar at least one week before the examination is to be taken, and in September and May at least one week before the first day of the respective examination periods (in 1914-15 not later than Monday, September 7, and Saturday, April 24, respectively). For later application an additional fee of $5 for any examination or series of examinations will be charged. Applications must be made on blanks (one for each course) to be obtained from the Registrar.

During the academic year students will be held responsible for the receipt of reports and other official communications sent to them at the coat room in University Hall. During the summer vacation they will be held responsible for the receipt of such communications sent to their home address as given on their registration blank for the preceding academic year.

SCHOLARSHIPS

Fifty scholarships of $250 each, payable in semi-annual instalments during the maintenance of a satisfactory grade, are available to students in Mining, Engineering and Chemistry who are in good academic standing, and in need of pecuniary aid. The awards are not based on competitive examinations. Scholars are not exempt from the payment of fees.

Applications for appointment or reappointment should be made on blanks furnished by the Secretary of the University, and filed with him on or before May 1.

As far as possible awards will be made not later than July 1 by the Committee on Scholarships. Scholarships not allotted at this time, or becoming vacant, may be filled by the Committee at its discretion.

In detail these Scholarships are as follows:

Open to students who have been in the University at least one year: 7 J. Pierpont Morgan, 7 Cornelius Vanderbilt, 10 D. Willis James, 1 Morris K. Jesup, 1 Samuel D. Babcock, 1 Oswald Ottendorfer.

Open to students of any class—8 Faculty, 15 Special. The Richard Butler scholarship open to students born in Ohio (for special regulations see University catalogue) has an annual value of $200.

In addition 40 Pulitzer Scholarships, carrying free tuition and a stipend of $250, are open to competition by graduates of the New York City High Schools.

Marcus Daly Scholarship in Mining Engineering

The Marcus Daly Scholarship of the annual value of $1,000, maintained by Mrs. James W. Gerard in memory of her father, is open to that worker or descendant of a worker in the Montana mines who passes the best competitive entrance examinations. The winner holds the same throughout his course in mining engineering and is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science. The next scheduled competition will be in 1915.

Class of '85 Scholarship

The class of '85 scholarship is open to duly registered students in the Schools of Mines, Engineering and Chemistry, and the holder is entitled to receive the net annual income of the class of '85 School of Mines Scholarship Fund of $9,000. The holder is subject to all the rules and regulations governing scholarships awarded under the jurisdiction of the Faculty of Applied Science.

Burgess Scholarships

Two scholarships, to be known respectively as the Daniel M. Burgess and the Annie P. Burgess Scholarships, are awarded annually to worthy and deserving young men of good habits and Christian character

who are unable to pay their own expenses while at the University. The amount of each scholarship is the annual income of $5,000.

Trowbridge Fellowship

A fellowship, known as the William Petit Trowbridge Fellowship in Engineering, is awarded by the Trustees on the recommendation of the Trowbridge Fellowship Committee. The incumbent will receive the net annual income of the fund of $10,000 established in memory of the late Professor Trowbridge.

Cutting Fellowships

The William Bayard Cutting Traveling Fellowships are awarded annually by the Trustees to graduate students who have given evidence of ability to make contributions of value to letters, science, law, medicine, or the fine arts. These Fellowships are open to men who have been in residence as graduate students and candidates for a higher degree under the Faculties of Political Science, Philosophy, or Pure Science for a least one academic year, and to graduates of Columbia University in Law, Medicine, Applied Science, or the Fine Arts who have had at least one year of additional study as graduate students in this University. In addition, not more than two members of the senior or graduating class in Columbia College may be appointed to such Fellowships in any one year.

Holders of these Fellowships are required to pursue their studies either in the United States or in foreign countries under such direction as may from time to time be prescribed. The stipend of each Fellowship will be fixed at the time of its award and will depend upon the requirements and purposes of individual Fellows. The normal minimum stipend will be $1,000. The appointments to these Fellowships will be made by the Trustees at their stated meeting in June of each year, and the Fellowships will be available from July 1st following. Applications must be submitted on or before April 1st of the year in which the award is to be made.

Industrial Research Fellowship

An Industrial Research Fellowship was established for the year 1913-14 by the American Brake Shoe and Foundry Company of New York, for the investigation and study of materials to improve the tractive force and wearing qualities of brake shoes as used in railroad service. The work is to be carried out in the chemical laboratories of the University and in one of the plants of the American Brake Shoe and Foundry Company in Mahwah, New Jersey.

The fellowship has a value of $2,500, $1,800 of which is for stipend and $700 for the expense of materials and apparatus in connection with the investigation.

MEDALS AND PRIZES

Medal Barnard

A gold medal valued at $200, endowed by President Barnard, is awarded quinquennially (next award, 1915) on the recommendation of the National Academy of Science to the person who within the five years next preceding shall have made such discovery in physical or astronomical science, or such novel application of science to purposes beneficial to the human race as shall be esteemed most worthy of such honor. For details and for a list of previous awards see the Annual Catalogue of the University.

Illig Medals

A bequest of $2,000 by William C. Illig, E.M., '82, provides for the annual award of medals to the student or students in the graduating class of these Schools who shall, in the judgment of the Faculty, have merited the same by commendable proficiency in their regular studies.

Darling Prize

A prize in Mechanical Engineering, the income of $1,000, bequeathed by Edward A. Darling, formerly Superintendent of Buildings and Grounds, is awarded annually to the most faithful and deserving student of the graduating class in mechanical engineering, the recipient to be chosen by members of the graduating class in that Course from among three names to be chosen by the Faculty.

OPPORTUNITIES FOR ADVANCED INSTRUCTION AND RESEARCH

Special attention is called to the opportunities offered through the Faculty of Pure Science for advanced instruction and research in Mining Engineering, Metallurgy, Civil Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, Chemistry, and Highway Engineering, leading to the degrees of A.M. and Ph.D., in accordance with the following provision: Students holding the required first degree who are primarily registered in a professional school of Columbia University, or in an allied professional school, may, with the consent of the faculty of such school, be registered as candidates for the higher degrees in the Faculty of Political Science, the Faculty of Philosophy, or the Faculty of Pure Science. In such a case the candidate must take his major subject under one of these Faculties, and must conform to all its rules as regards examinations, essay, and dissertation; but he may offer as the equivalent of four full courses for the degree of Master of Arts and of the two minor subjects for the degree of Doctor of Philosophy such of his professional courses as may be approved for that purpose by the Dean of the Graduate Faculties. A statement of the general regulations governing graduate work is printed in the *Announcement of the Faculties of Political Science, Philosophy, and Pure Science,* which may be had upon application to the *Secretary of the University.*

An outline of the courses in the Schools of Mines, Engineering and Chemistry which may be offered toward the higher degrees will be found in this Announcement on pp. 81, 87, 104, 109, *et seq.*

A separately printed pamphlet descriptive of the work in Highway Engineering may be had upon application to the Secretary of the University.

UNIFORM CURRICULUM FOR THE FIRST YEAR*

The curriculum for what was formerly the first year of the four-year courses leading to the degrees of Engineer of Mines, Metallurgical, Civil, Electrical, Mechanical and Chemical Engineer and Chemist, the requirements of which must be fulfilled by the student entering the second-year class in 1914, is printed below.

As will be seen in this tabular statement, this year was mainly devoted to a thorough grounding in Mathematics, Physics and Chemistry, the three fundamental subjects which form the indispensable basis for all broad and successful engineering work, not only in the remaining years of the course, but throughout the entire professional career. Specialization begins to some extent in the second year, and becomes more marked in the third and fourth years.

First Half Year			Hours per week	
See Page			Class	Lab'y
82	Drafting 1	Engineering Drafting	1	14
82	Drafting 3	Descriptive Geometry	3	
89	Mathematics 1	Algebra	2	
89	Mathematics 3	Analytical Geometry	3	
110	Mechanics, 1	Elementary Mechanics	2	
109	Phys. Educ. A	Gymnasium		2
110	Physics 3	Mechanics, Wave-Motion and Heat	5	
		Total..	16	16
Second Half Year				
76	Civil Eng. 2	Theory of Surveying	2	
70	Chemistry 4, 62	General Chemistry and Qual. Analysis	5	15
89	Mathematics 64	Calculus	5	
109	Phys. Educ. A	Gymnasium		2
110	Physics 4	Heat and Light	5	
		Total..	17	17
SUMMER WORK: Civil Eng. 15s. Five weeks of surveying practice.				

*The courses in this year will not be given during the academic year 1914-15 or thereafter, in the present undergraduate courses in the Schools of Mines, Engineering and Chemistry leading to the various professional degrees.

MINING ENGINEERING

General Statement

The instruction in the School of Mines during the first and second years includes fundamental training in mathematics, physics, mechanics, chemistry, mineralogy, and geology, as outlined in the program of studies on pages 30 and 36. Laboratory instruction in chemistry, assaying, drafting, mineralogy and geology extends through three years.

The engineering, mining, and metallurgical laboratories are equipped to train the student in the making of scientific tests of engineering materials, and working tests of machines and processes of ore treatment, thus preparing him, as far as it is possible in the school, for work that he will be called upon to do as an engineer.

Practical instruction in summer classes in the field is made an important feature of the curriculum. Details of the summer courses in mining, metallurgy, field geology and surveying will be found on pages 34 and 35.

While much time is given to practical training in the laboratories, in the field, and at the mines and metallurgical establishments, care is taken to subordinate this instruction to a high standard of accomplishment in classroom work.

Advanced students and graduates can choose their subjects and plan of work much more freely than undergraduates. Suggestions as to graduate work will be found on page 109.

Location—Many coal, iron, and other mines, together with quarries and metallurgical works, are easily accessible from New York in from one to four hours by rail. Among these are magnetite iron mines in New York, New Jersey, and Pennsylvania; stone quarries in the same States, and in Connecticut; anthracite and bituminous coal mines, and natural gas and oil wells in Pennsylvania, and zinc mines in New Jersey. New York and the adjacent States produce each year about half the pig-iron and coal, and over fifty per cent. of the total value of the mineral product of the whole country. There are within easy reach of New York City iron blast furnaces and some of the most skilfully designed and managed steel works, rolling mills, steel and iron foundries, copper smelting and refining works, lead-refining works, zinc works, and electrolytic establishments in the world. New York City, moreover, is the headquarters of many corporations operating mines and metallurgical works in this and other countries. Within a radius of one hundred miles may be studied many phases of the best practice in mining and metallurgy in the country. By going a little farther one may reach the bituminous coal fields and the natural gas, oil and salt regions in one direction, and the pyrite deposits, and granite and marble quarries of New York and New England in the other; while the excursions of the summer class in mining extend as far as the copper, iron, zinc, lead, silver, and gold regions of Michigan, Missouri, Montana, Colorado, California, Arizona and Utah (see page 34).

Building—The six-story School of Mines building is 145 feet long by 57 feet in width. The basement and sub-basement contain the ore-dressing laboratories. On the main floor are the mining and metallurgical museums and lecture rooms. On the second floor are the offices of the department of mining, the mining and metallurgical department libraries, a drafting-room for the design work of the fourth year, and one of the metallurgical laboratories. On the third floor are the offices of the department of metallurgy, the furnace rooms, the chemical laboratory, metallographic laboratory, and the research laboratories of the same department. On the fourth floor are the assay laboratories.

Equipment

Lecture Illustrations—The lectures on mining are illustrated by sets of books aggregating over 300 volumes, each student having the use of books of prints for home study and for reference during the lectures. These illustrations are supplemented by working blue prints, enlarged bromide prints and other wall diagrams.

Mining Library.—The University library contains sets of the transactions of all mining, metallurgical, and engineering societies, and of the more important periodical publications on these subjects. There is also a large collection of books on mining, and all new publications of value are added as they appear. In addition, a selected departmental library is maintained, which is accessible to students at all times.

Mining Museum—The subject of mining is illustrated by collections, as follows: Maps of coal and metal mines of this and other countries. Working drawings, diagrams, and photographs of mine plant, and of mining and dressing machinery. Models of mines and parts of mines, and of mine plant. Mining tools: picks, shovels, hammers, drills, blasting apparatus, lamps, safety-lamps, anemometers; and machine drills. Ores and dressing products from typical works in this and other countries. Surveying instruments: geological compasses and clinometers, attraction compasses, dipping needles, hanging compasses and arcs, transits, lamp signals, rods, and apparatus for plumbing and measuring shafts.

Among the more notable exhibits is a relief model of one of the mines of the Cleveland-Cliffs Iron Mining Co. of Michigan, a similar model of a typical gold mine in Colorado, and a set of three glass models and two relief models of the Copper Queen mine in Arizona, a model of the mine workings in the Mahanoy and Shenandoah anthracite coal basins Pennsylvania, a glass model of the mine workings on the Calumet Conglomerate of Houghton County, Michigan, a model

of a standard oil-well drilling rig, and a model of the St. Joseph Lead Co.'s dressing works at Bonne Terre, Missouri. There is also a collection of working drawings of mine plant, and a collection of underground photographs, taken by magnesium light.

Mining Laboratories—These laboratories, occupying seven rooms, include the following:

The Laboratory for Mechanical Assays contains appliances for quantitative work in hand picking, jigging and vanning small samples of ore, and for panning gold-bearing gravel. For small scale working tests there are a number of specially designed laboratory classifiers, jigs, sand and slime tables.

The Crushing and Sampling Laboratory contains machinery for crushing and sampling large and small lots of ore, including gyratory and jaw crushers, rolls, a sample grinder, ball and pebble mills for fine crushing, gyratory screens, automatic samplers, and laboratory crushers, together with sieves, riffle samplers, etc.

The Laboratory for Working Tests contains an air jig, a buddle, a keeve, magnetic and electrostatic separators, and other similar apparatus for working a ton or more of ore at a time.

The Laboratory of Ore-Dressing Machinery contains full-sized machines of standard types. The apparatus now installed includes two Harz jigs of two and three compartments; a Hooper vanning jig, a Richards' pulsator jig and two pulsator classifiers, two conoidal round tables, concave and convex; a Johnston vanner, a Wilfley table, a Deister slimer, and a Stein-Bilharz belt table. On the floor below are full-sized classifiers, dewatering cones, automatic feeders, and centrifugal pumps for supplying these machines with water and ore for continuous work.

Mining Laboratory Instruction

The work required is designed (1) to illustrate the physical laws and practical conditions affecting the mechanical concentration, separation, and purification of minerals; (2) to instruct the students in the details of quantitative working tests on both small and large scale; (3) to train them in the adjustment and operation of the standard types of concentrating machines, and in testing the efficiency of such machinery in actual operation, and (4) to give opportunity for original research.

The work includes the reduction of a ton or more of ore to laboratory samples, and tests on portions of this ore by handpicking, hand jigging, and mechanical treatment on laboratory jigs, classi-

fiers, and slime tables, to determine the proper method of mill treatment. These tests are controlled by crushing and vanning samples of the products, and reports of the results obtained are made in a systematic manner.

The large concentrators are arranged to be run continuously, for as many hours as may be necessary, using the same ore and the same water again and again. This is accomplished by running the products of the several machines through dewatering cones, from which the mixed material is transferred to the hoppers of automatic feeders. Variable speed pulleys permit any desired adjustment of the driving mechanisms. The water supply is drawn from a constant level tank fed by a centrifugal pump, and is regulated by dial cocks. Other adjustments are equally under control and can be varied at will.

With each of these machines the student makes a series of experiments. These include the adjustment and regulation of the ore supply, of the feed and wash water, of speed, stroke, and other working conditions, to the treatment of different ores and different grades of sand and pulp. In this work the student is taught to recognize the symptoms of irregular working, to diagnose the trouble with the aid of laboratory tests, and to apply the proper remedy. Incidentally he makes tests of capacity and efficiency, taking frequent samples of the ore feed, and of the different products for quantitative examination, and weighs and measures the ore and water supply and products obtained.

Experiments of this kind for purposes of instruction cannot well be made at concentration works in the field. There the machines must work regularly and without interruption, and any interference with the ore feed, water supply, or other adjustments may occasion loss of valuable mineral.

Research Work—The laboratories have facilities for original investigation in the physical laws controlling the mechanical treatment of minerals.

Original researches have recently been undertaken by graduate students in investigation of magnetic fields with reference to ore-concentration; the effect of variations in the speed of crushing machinery on the production of undersized material; the amalgamation of gold ores; an investigation of the laws of jigging.

Summer Courses

Summer Courses in Surveying—About five weeks' work in surveying is required of each class between the first and second years, and eight weeks between the second and third. See pages 46 to 47.

Summer Course in Mine Surveying—Following the 13 weeks of prescribed field work in surveying, one week is spent in underground

surveying at a mine. In 1909 and again in 1910 this work was done at the Orchard Mine, Wharton, N. J.; in 1911, 1912 and 1913, at workings of No. 3 shaft, of Lehigh Valley Coal Co., Hazleton, Pa.

Summer Course in Practical Mining—Six weeks are spent in detailed study of the plant and methods of working at some mine or mines and in visits to other mines and mining regions. The course includes shaft-sinking, drifting, stoping, timbering, underground haulage, hoisting, mine drainage, ventilation, surface plant, mine buildings, repair shops, etc., organization and administration. Arrangements are made at selected mines, by which the students, singly or in small squads, may do the work described above according to a definite plan and under the general direction of the department.

These summer courses have been in operation since 1877, and have proved themselves an indispensable adjunct to the regular curriculum. They bear the same relation to the study of mining as laboratory work to the study of chemistry or physics, or clinical instruction and hospital practice to the study of medicine.

In 1910, the class, numbering 43 men, was scattered through 16 States and for the required work visited over 60 mines.

In 1911, the class numbered 40 men, who studied at gold, silver, copper, lead, zinc and coal mines, in 12 different states.

In 1912, the class of 37 men studied at gold, copper, iron and coal mines, in Colorado, Montana, Nevada, Alaska, Michigan, Tennessee, New York, Pennsylvania and New Jersey. The time occupied was from 6 to 11 weeks.

In 1913 the class of 35 men studied at gold, silver, copper, iron, coal and pyrite mines, in Colorado, Michigan, Wisconsin, Minnesota, Arizona, Mexico, West Virginia, Pennsylvania, New York, New Jersey and Canada. The time occupied was from 6 to 10 weeks.

Summer Course in Metallurgy—Students are required to devote six days to the study of metallurgical plants in the vicinity of New York, where the smelting of copper and lead ore and the refining of copper and lead bullion may be seen, or the men may study metallurgical plants in the West, situated near the mines to which they may be assigned for their summer work in mining. A full report is required of each student.

Summer Courses in Geology—One week is devoted to practical field geology. The class is instructed in methods of field observation, locating outcrops, measuring dip and strike, keeping notes, etc., afterward constructing maps and geological sections from the observations noted; all under the supervision of the Professor of Geology.

ENGINEER OF MINES

The four-year course leading to the degree of Engineer of Mines is intended primarily to train men to undertake the development of mineral properties, the design and construction of mine plants, and to manage mines. It is necessarily a broad one, comprising a wide range of studies in pure and applied science, and for this reason is frequently taken by students desiring a general scientific training.

The subjects most emphasized in this course are mining, metallurgy, geology, and engineering. Metallurgy requires knowledge of inorganic and applied chemistry, qualitative and quantitative analysis, and assaying. Geology must carry with it preliminary training in crystallography, mineralogy, and petrography.

Engineering in all its branches needs a fundamental knowledge of mathematics, physics, mechanics, and thermodynamics. The proper design and construction of mining plants involves the study of certain branches of civil engineering, and the many and increasing applications of machinery to mining make it necessary to give much time to the theory and practice of mechanical and electrical engineering.

FIRST YEAR

See page 30

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
76	Civil Eng. 23	Theory of Railroad Surveying	2	3
82	Drafting 7	Structural Drafting		3
87	Geology 5	General Geology	3	
90	Mathematics 65	Calculus	5	
105	Mineralogy 1	Mineralogy	3	6
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
		Total..	18	14
Second Half Year				
73	Chemistry 66	Quantitative Analysis	3	12
75	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of the Dynamo	2	
87	Geology 6	General Geology	3	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 2	Mineralogy	3	3
109	Phys. Educ. B	Gymnasium		2
		Total..	19	17

SUMMER WORK: Civil Eng. 27s and 28s, Practical Surveying (eight weeks).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
88	Geology 105	Economic Geology	3	
90	Mech. Eng. 13	Steam Power Machinery	3	
104	Metallurgy 81	Assaying	2	9
106	Mining 51	Excavation and Tunneling	3	
		Total..	16	15
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials—problem work		3
79	Civil Eng. 64	Graphic Statics	1	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
87	Geology 4	Petrography (6 hrs. for 2 months)		3
88	Geology 106	Economic Geology	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
97	Mech. Eng. 80	Experimental Mechanical Laboratory	1	3
105	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 mos.)		3
106	Mining 52	Boring & Shaft Sinking	2	
106	Mining 54	Methods of Mining	3	
		Total..	16	18

SUMMER WORK: Field work, Mining, Metallurgy, and Geology (9 weeks).

FOURTH YEAR

		First Half Year		
84	Elect. Eng. 75	Alternating Current Laboratory	1	3
88	Geology 101	Applied Petrography (elective)		
90	Mech. Eng. 17	Engineering Thermodynamics	2	
100	Metallurgy 101, 111	Introduction to Metallurgy and Metallurgy of Copper	3	
101	Metallurgy 131	Metallurgy of Iron and Steel	1	
	Metallurgy 141	Electro-Metallurgy	1	
107	Mining 71	Mine Plant	3	
107	Mining 73	Mine Constructions	1	
107	Mining 75	Design of Mine Plant		12
108	Mining 81	Ore Dressing	4	
108	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
79	Civil Eng. 76	Hydraulics	2	
87	Geology 16	Paleontology (elective)		
88	Geology 102	Petrography of the Ores (elective)		
88	Geology 110	Geological Surveys	2	
97	Mech. Eng. 74	Gas Power Machinery	2	
103	Metallurgy 72	Metallurgical Laboratory (10 afts)		2
101	Metallurgy 122	Metallurgy of Gold, Silver, etc.	3	
106	Mining 56	Mine Engineering	3	
107	Mining 72	Mine Plant	3	
107	Mining 78	Thesis		12
108	Mining 80	Mill Constructions	1	
108	Mining 82	Ore Dressing (Lab.)—(afts. of 3 weeks)		3
108	Mining 94	Mining Law	2	
		Total..	18	17

METALLURGICAL ENGINEERING

General Statement

The primary aim of the four-year course leading to the degree of Metallurgical Engineer is to train students to take laboratory or administrative positions in metallurgical works.

The undergraduate instruction consists of (1) class-room work, lectures, conferences, study of text-books; (2) general laboratory work in metallurgy; (3) training in planning and executing original research; (4) summer courses and visits to industrial metallurgical works.

Much importance is attached to a thorough training in the fundamental subjects, mathematics, chemistry, physics, geology, mineralogy, and engineering, and to the higher branches of engineering, chemistry and important courses in mining engineering, with a view to their applications to metallurgical practice.

Great stress is laid on the original planning and executing of work, which is done under the direction and criticism of the instructors.

The instruction in metallurgy is based on advanced practice in the science from the introductory courses in metallurgy to the advanced special courses in the various branches of the subject.

To graduate and other *advanced students* and properly qualified *practitioners,* the department's laboratories are open under generous restrictions.

Location and Equipment

Location—For the advantages of New York and the adjacent states see page 31.

Metallurgical Establishments Accessible—Some of the largest and most advanced iron, steel, copper, lead, zinc, and electrometallurgical works in the world are accessible to students of the School of Mines for the study of the best metallurgical practice. See also page 31. The summer classes visit in different years metallurgical establishments in all parts of the country, including the extreme West and South.

Building—The department occupies about half the School of Mines Building. See page 32.

Collections—There are large and growing collections of lecture diagrams; of models and working drawings of metallurgical furnaces and machinery; of apparatus for lecture demonstration and illustration of metallurgical principles and processes; and a very large collection of metallurgical specimens and suites, with descriptive and explanatory notes.

Metallurgical Laboratories—There are four specially equipped metallurgical laboratories which serve four chief purposes: (1) to give skill in the use of the instruments of precision of the art; (2) to teach the underlying principles of metallurgy and give familiarity with the conditions, especially to to high temperature, under which metallurgical operations must be carried on, and the use of the principal types of furnaces and other metallurgical apparatus, or in short "Analytical metallurgy"; (3) to give some aquaintance with certain industrial metallurgical processes, or what may be called "Applied metallurgy"; and (4) to give advanced students and qualified practitioners the means of making metallurgical and metallographic researches.

Instruments of Precision—Standard pyrometers, such as the Le Chatelier thermo-electric pyrometer, the Wanner optical, and the Fery radiation pyrometer, are used for the determination of high temperatures; sclerometers for measuring hardness of metals and alloys; Fremont and Brinell impact testing machine; a tensile testing machine; a Berthelot calorimeter for testing fuels; and many other instruments for the determination of the physical properties of metals and alloys.

Non-Ferrous and Electrometallurgical Laboratory—A. For wet and dry metallurgy, the extraction, refining, and alloying of the non-ferrous metals, there are ore-roasting furnaces; gas-fired crucible furnaces; assay muffle furnaces; a high temperature forge; leaching plants; a filter press; amalgamating pans; a chlorinating barrel; ball mills; desilverization kettles; and pyrometers. B. For electrometallurgy, the electrical recovery, deposition, refining, and alloying of metals, there are storage batteries; a 30 K.W. motor-generator set for supplying direct current at high amperage and a range up to 25 volts; electrolytic refining vats; small electric furnaces of the Moissan arc, Borchers arc and resistance types; and large experimental melting, smelting, and refining furnaces.

Iron and Steel Laboratory is equipped with electric and double muffle gas furnaces especially designed for this laboratory, in which

a number of full-sized tensile test bars may be heated simultaneously to any temperature up to 1300° C., with uniformity and precision; gas crucible furnaces; gas forges; special furnaces; and small power-driven rolls for studying the influence of the conditions of rolling on the properties of metals.

The Metallographic Laboratories, for the miscroscopic and pyrometric study of metals, mattes, speiss, slags, ores, etc., have microscopes of the Leitz, Le Chatelier, and other types; equipment for illumination and photography; electric resistance furnaces of different types; portable gas furnaces; and pyrometers. The metal-working shop has power-driven machines for cutting specimens, etc.

The Assay Laboratory has for its main equipment thirty-six gas-fired muffle furnaces, with a corresponding number of desks, which are arranged in rows with a furnace facing each desk. There are, also, a sufficient number of coke pot, coal muffle and gasoline furnaces for the student to become familiar with these types. The usual balance, grinding, and cupel rooms are provided.

Supplies—There is a large stock of ores, irons, steels, alloys, refractory materials, fluxes, etc., which may be used for investigations.

The Metallurgical Library containing over fifteen hundred volumes of metallurgical treatises, text-books, periodicals, etc., is open to all students, and to others properly introduced. Books may be borrowed under suitable restriction.

Metallurgical Laboratory Instruction

In order to become familiar with a wide range of the conditions and principles of metallurgy, the student conducts experiments, each illustrating, testing, or aiming to discover some one or more metallurgical principles or reactions, or the conditions which permit a given reaction to occur. He must, in general, after each experiment enunciate briefly in writing, the law to which his results point, or indicate how far those results severally and collectively support or oppose a given proposition.

These experiments relate chiefly to such subjects as the influence of thermal treatment on the properties and microstructure of metals and

alloys; the determination of melting points and other temperatures; the relation between the composition of mattes and slags and their fusibility; the influence of fluxes; the behavior of refractory materials at high temperatures, either alone or in contact with different slags; the temperature limits and the reactions of roasting operations; the influence of various bodies on the reactions which take place in roasting, in the cyanide process, in the chlorination process, and in pan amalgamation; the interaction of carbon and molten oxides, sulphides, silicates, etc., etc.

Summer Courses

Summer Courses in Metallurgy—No. 62s for mining engineers consisting of visits to non-ferrous metallurgical plants for a period of one week.

For metallurgical engineers the summer course lasts six weeks and includes No. 64s, visits to iron and steel metallurgical plants, and 66s, visits to plants for other metals. On these trips, which cover the practice in both the east and the west, the students are instructed in the actual metallurgical operations as carried on in the field. A prominent part of these courses consists of work such as making written descriptions of the processes, and sketches of the furnaces and other apparatus, with dimensions, usually from the student's own estimate; explaining the principles on which the processes rest, the reasons for the special shapes and sizes of the apparatus, the chief technical difficulties, how they are overcome, and by what tests the processes are controlled; giving the number of men, and, as far as practicable, the consumption of fuel and other materials, the thoroughness of recovery of the metal sought, etc. From an imaginary set of prices and wages, the students calculate the cost and profit of certain operations.

Summer Courses in Surveying—About thirteen weeks' work in surveying is required of the class between the first and second years. See pages 46 and 47.

Summer Courses in Geology—After the third year at least one week is devoted to practical field geology. For details see page 89.

Metallurgical Excursions—At stated times excursions, open only to students in Metallurgical Engineering, are made to the neighboring foundries, machine shops, mines, and other points of interest. The students attend these excursions in squads of such size that proper individual instruction can be given to each member of the squad.

METALLURGICAL ENGINEER

This course, which covers four years, is intended for those who expect to follow metallurgical work and become trained metallurgists in any of the branches of the profession. During the first two years attention is paid to a thorough training in fundamental subjects, especially in mathematics, chemistry, physics, geology, mineralogy, and preliminary courses in engineering. In the third year instruction is given in metallurgy and in mechanical, electrical and mining engineering, chemistry, mineralogy and geology. The fourth year is devoted largely to advanced lecture courses and laboratory work in metallurgy, to important courses in mining engineering, and to the higher branches of engineering and chemistry.

In the summer schools, instruction is given in general surveying, in railroad work, geological field work, and visits are made to metallurgical works. In the six weeks' summer courses at metallurgical works the students are required to study processes, make dimension sketches of furnaces and mills, and by observation and instruction become acquainted with metallurgical operations as conducted at the time.

FIRST YEAR

See page 30

SECOND YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
76	Civil Eng. 23	Theory of Railroad Surveying	2	3
82	Drafting 7	Structural Drafting		3
87	Geology 5	General Geology	3	
90	Mathematics 65	Calculus	5	
105	Mineralogy 7	Mineralogy	3	3
109	Phys. Educ. B.	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		6
		Total..	18	17
		Second Half Year		
73	Chemistry 66	Quantitative Analysis	3	12
75	Chemistry 82	Industrial Chemistry	3	
83	Elect. Eng. 2	Elements of the Dynamo	2	
87	Geology 6	General Geology	3	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 8	Mineralogy	3	3
109	Phys. Educ. B.	Gymnasium		2
		Total..	19	17

SUMMER COURSES: Surveying Practice 5 weeks (Civil Eng. 27S).
Surveying Practice 3 weeks (Civil Eng. 28S).

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	6
88	Geology 105	Economic Geology	3	
90	Mech. Eng. 13	Steam Power Machinery	3	
104	Metallurgy 81	Assaying	2	9
100	Metallurgy 101	Introduction to Metallurgy	1	
100	Metallurgy 111	Metallurgy of Copper	2	
		Total..	16	15
		Second Half Year		
79	Civil Eng. 64	Graphic Statics	1	3
79	Civil Eng. 78	Hydraulics	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
85	Elect. Eng. 104	Electric Distribution	2	
87	Geology 4	Petrography (6 hrs. for 2 months)		3
88	Geology 106	Economic Geology	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
95	Mech. Eng. 60	Hydraulic Laboratory		3
101	Metallurgy 122	Metallurgy of Lead, etc.	3	
105	Mineralogy 6	Optical Mineralogy (6 hrs. for 2 months)		3
106	Mining 54	Methods of Mining	3	
		Total..	18	15

SUMMER COURSES: Non-ferrous Works Visits 3 weeks (Met. 66S). Iron and Steel Works Visits 3 weeks (Met. 64S). Geology Field Work 1 week (Geol 112S).

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	
84	Elect. Eng. 75	Alternating Current Laboratory	1	3
90	Mech. Eng. 17	Engineering Thermodynamics	2	
103	Metallurgy 77	Metallurgical Plant Construction		3
101	Metallurgy 131	Metallurgy of Iron and Steel	1	
102	Metallurgy 141	Electrometallurgy	1	
102	Metallurgy 151	Constitution of Alloys	2	
103	Metallurgy 171	Metallurgical Laboratory		9
103	Metallurgy 175	Metallurgical Investigation	1	
107	Mining 73	Mine Constructions	1	
108	Mining 81	Ore Dressing	4	
108	Mining 91	Mine Administration and Accounts	2	
		Total..	18	15
		Second Half Year		
71	Chemistry 122	Physical Chemistry	3	
96	Mech. Eng. 72	Gas Power Machinery	2	3
97	Mech. Eng. 76	Standard Tests	1	3
101	Metallurgy 118	Advanced Metallurgy of Copper	1	
101	Metallurgy 128	Advanced Metallurgy of Lead, etc.	1	
102	Metallurgy 138	Advanced Metallurgy of Iron and Steel	1	
102	Metallurgy 148	Advanced Electrometallurgy	1	
102	Metallurgy 158	Advanced Course on Constitution and Property of Alloys	1	
103	Metallurgy 172	Metallurgical Laboratory		6
108	Mining 80	Mill Construction	1	
108	Mining 82	Ore Dressing		3
108	Mining 94	Mining Law	2	
		Total..	14	15

CIVIL ENGINEERING

General Statement

The four-year course leading to the degree of Civil Engineer is designed to afford a thorough analytical training in construction and management. The course contains numerous and extended practical exercises in those matters which pertain to the profession of the civil engineer in relation to all classes of structures and public works and in connection with the various developments and applications of power by the use of steam, electric, water, and air motors. This course is also designed to be an educational preparation for those duties or functions of an executive character whose discharge in connection with the management of public or other works requires, or is rendered more efficient through, a thorough knowledge of civil engineering. The breadth and nature of this educational training adapts it no less efficiently to the purposes of those who intend to follow callings not of an engineering character but which may be related more or less to manufacturing, to structural matters, or to the development and application of power. The theoretical portion of the instruction is based largely upon the courses given in the departments of Mathematics, Mechanics, and Physics, and the results obtained are applied to practical engineering work. Special stress is laid upon the design by the student of the various structures and machines which the civil engineer is called upon to construct or operate in the practice of his profession. The instruction is given by lectures, demonstrations by the student, and frequent conferences, co-ordinate with which the work of design is continuously carried on. It covers comprehensively the subjects of surveying, road and railroad engineering, water supplies of cities and towns, irrigation, sanitary engineering, including sewage disposal, both graphic and analytic treatment of all metallic structures, foundations, retaining and reservoir walls, high masonry dams, sewer systems, hydraulic engineering, rivers and harbors, pumping engines, hydraulic, steam and electric motors.

Ample facilities are afforded for post-graduate students in civil engineering, and special students are admitted to various engineering courses of the department upon evidence of proper qualifications.

Special provision is made for graduate work in Highway Engineering and allied subjects, leading to the degree of Master of Arts designed particularly for men engaged in the practice of Highway Engineering. This work is given during the months from December to March, both inclusive, a period equivalent to one half year. Opportunity is afforded for Highway Engineers to obtain advanced professional knowledge during the season of the year when leaves of absence from work may be easily obtained.

Equipment

The school possesses an unusually full equipment of engineers' and solar transits, levels, plane tables, compasses, and all accessories, as well as smaller instruments. Current meters, hook gauges, and floats of various types are also used in making observations on the flow in, and discharge of, rivers and canals. A complete set of sections of iron and steel shapes, models and photographs of engineering works, together with working plans of the latter, are in the department for the use of students. The hydraulic laboratory affords opportunity for the practical operations of measuring the discharge through weirs and other orifices, the flow through open channels and closed pipes, frictional and other resistances in pipes and open channels, as well as for meter gaugings, and for general hydraulic investigations. The testing work in the mechanical laboratory includes the complete tests of various structural materials in tension, compression, bending, and torsion, including the observation and digesting of all corresponding data.

A cement-testing laboratory is fully equipped with testing machines, briquette molds, tanks, and other apparatus requisite for all classes of investigations in the nature and physical properties of cements and cement mortars.

A complete laboratory for the testing of road materials has been established and is constantly in use for investigations connected with materials suitable for road building. The facilities offered by the laboratory are full and sufficient to make all tests required to determine resistance to abrasion, classification of sand, gravel and broken stone and the cementing power of all qualities of road materials. This equipment also includes complete facilities with all modern apparatus used in the determination of the physical and chemical properties of bituminous materials. The laboratory is at the service of students and is used by them, both for the ordinary prosecution of studies to which the determination of results is related and for the purposes of thesis work, and other similar investigations.

The Materials Testing Laboratory is located at the north end of the main floor of the Engineering Building. It is fully equipped with modern appliances for the conduct of tests upon all structural materials. There are seven testing machines varying in capacity from 600 lbs. to 400,000 lbs., representing all American types, including a 150,000-lb. Emery hydraulic power machine, which is a standard of accuracy, and the refinement of mechanical construction. These machines are suited to make tension, compression, transverse and torsion tests upon metals, also to make all desired tests upon building materials, such as timber, stone, brick, concrete blocks or concrete-steel beams, columns, partition blocks, and all built up materials.

The laboratory is also liberally supplied with a large assortment of

extensometers, deflectometers, micrometers, gauges, and similar instruments of precision for measurement of test pieces.

Other apparatus, such as delicate scales of different sizes for use in absorption and freezing tests on building materials, also pyrometers and furnaces for the conduct of fire tests upon all kinds of fire-resisting materials are available.

General Statement of the Summer Courses in Surveying and Geodesy at Camp Columbia, Morris, Conn.

The instruction in Surveying given by the Department of Civil Engineering consists of lectures, recitations and problem work, supplemented by instrumental practice in field work, and office work in computation and mapping. The general lectures and recitations are given at the University. The field practice is given during the three summer vacations of the regular four-year course. The subject of Geodesy is given by the Department of Astronomy, and the practical work connected therewith is done under the supervision of that department by students in Civil Engineering during a portion of five weeks of the summer vacation between the third and fourth years. The theory of Plane Surveying, including Railroad Surveying, is given by the Department of Civil Engineering. The field practice is conducted under the administration of the Summer Session at Camp Columbia, a point in the country near Litchfield, Conn., where ample facilities are provided for all requisite operations, and where the topography and climate are admirably adapted to the practical work of surveying. Five weeks' continuous attendance is required of all students in the Schools of Mines, Engineering and Chemistry during the summer betwen the first and second years. (See C.E. **15S**, page 76.) Five weeks' additional attendance is required of all students in Civil Engineering (see C.E. **25S**, page 77), and eight weeks of all students in Metallurgy, and eight weeks of all students in Mining (see C.E. **27S** and **28S**, page 77), during the summer between the second and third years. Nine weeks' continuous attendance is required of all students in Civil and Sanitary Engineering during the summer between the third and fourth years (see C.E. **26S**, **26aS**, Astronomy **107** and C.E. **71S**, pages 77, 70 and 79). During the summer of 1914 the Summer Courses in Surveying and Geodesy will be in session about thirteen weeks. Students are referred to the special announcement of the Summer Session at Camp Columbia for other details.

No student taking these courses will be excused from any part of any course on account of work done elsewhere, unless that work has been done under the immediate direction of an instructor of an institution which grants degrees in Mining or Civil Engineering. In some exceptional cases, however, credit will be given upon the evidence of field notes, maps and reports presented to the professor in charge of the courses.

Students who fail to receive a passing mark in C. E. 2 but receive a grade of D will be allowed to take course 15, but must take the regular deficiency examination in C.E. 2 in September.

The University provides houses or tents having elevated floors, furnished with cots and drafting tables. There are also provided a dining hall and bath house. Arrangements may be made for laundry work to be done in the neighborhood. A supply of drafting materials (not instruments) is kept on sale. Especial attention is given to the wholesome and substantial character of the table.

The cost of board is about $6.75 per week and is charged against the individual deposits. The account against each student is reckoned from the day announced for his division to assemble. No allowances or reductions are made for absences of less than one day. Due notice must be given to and excuse granted by the officer in charge at least one day in advance of the beginning of such absence.

Every student must be present on the day appointed for his division to assemble, unless other arrangements have been made with the officer in charge. Failure to comply with this regulation may be sufficient cause to refuse the applicant's admission to the courses.

For fees and deposits for these courses see page 21.

For the session of 1914 the school will open May 30 and close August 31. The schedule of attendance is as follows:

May 30—Session opens and students report for courses C.E. 15S,[1] 25S and 27S.[2]
June 30—Students report for courses C.E. 26S, 26aS and Ast. 107S.
July 4—Students assemble for courses C.E. 15S, 25S and 27S.
August 5—Students assemble for course C.E. 71S.
August 8—Students assemble for course C.E. 28S.
August 31—Session ends.

[1]Open only to students who are deficient in this course, students who will attend the Summer Session in New York or those assigned to this division on basis of scholarship. All other students report July 4.

[2]It will be to the advantage of students taking this course to report on July 4, and having finished the course, to continue with course C.E. 28S.

CIVIL ENGINEER

FIRST YEAR

See page 30

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
70	Botany 7	Growth and Character of Timbers	1	3
82	Drafting 5	Graphics		3
90	Mathematics 65	Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
105	Mineralogy 5	Minerals of Building Stones	2	3
106	Mining 53	Excavation, Tunneling, Boring and Shaft-sinking	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physics Laboratory		3
112	Shop Work 15	Forging and Foundry Practice		3
		Total..	18	17
Second Half Year				
75	Chemistry 82	Industrial	3	
82	Drafting 6	Graphics		3
82	Drafting 8	Structural Drafting		6
83	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	*3
90	Mech. Eng. 14	Steam Power Machinery	3	
110	Mechanics 102	Analytical Mechanics	5	
101	Metallurgy 134	Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physics Laboratory		3
112	Shop Work 16	Machine-work		3
		Total..	18	18

*Saturday P.M., 1 afternoon during April and May—equivalent 1 hour.

SUMMER WORK: Practical Surveying Civil Eng. 25S—5 weeks.

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
70	*Astronomy 105	Geodesy	3	
76	Civil Eng. 21	Roads, Streets and Pavements	1	
77	Civil Eng. 51	Railroad Surveying	2	3
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
78	Civil Eng. 59	Sanitary Treatment of Water Supply and Sewage	2	
78	Civil Eng. 61	Theory of Trusses	2	3
90	Mech. Eng. 17	Engineering Thermodynamics	2	
97	Mech. Eng. 77	Standard Tests	1	3
		Total..	18	15
		Second Half Year		
70	Astronomy 106	Geodesy	1	3
77	Civil Eng. 52	Railroad Surveying	3	3
77	Civil Eng. 54	Resistance of Materials (Problems)		3
78	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
90	Mech. Eng. 18	Engineering Thermodynamics	2	
97	Mech. Eng. 78	Kinematics	3	
		Total..	17	18

SUMMER WORK: { Hydrographic Surveying—Civil Eng. 26S; Geodetic " —Astronomy 107S } 5 weeks.
Railroad surveying practice—Civil Eng. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
79	Civil Eng. 75	Hydraulics	3	
79	Civil Eng. 85	Foundations	2	
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	3	
81	Civil Eng. 99	Thesis	2	
93	Elect. Eng. 5	Alternating Current Engineering	1	
95	Elect. Eng. 75	Alternating Current Laboratory	1	3
84	Mech. Eng. 41	Machine Design	1	3
85	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	18	15
		Second Half Year		
79	Civil Eng. 88	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 90	Railroad Engineering	3	3
80	Civil Eng. 94	{ Design and Construction of Sewers; River and Harbor Improvement }	2	
81	Civil Eng. 100	Thesis	3	3
85	Elect. Eng. 112	Electric Railway	2	3
89	Law 2	Business Law	2	
93	Mech. Eng. 46	Hydraulic Turbines	3	
		Total..	17	12

*In 1914-15 courses 105 and 106 will be combined into a single course, given during the second term in an abbreviated form, Professor Jacoby being absent on leave during the first term.

SANITARY ENGINEERING

General Statement

The course in Sanitary Engineering is a differentiation from the regular course in Civil Engineering and naturally leads, therefore, to the same degree. The first year is identical with the first year of other engineering courses, while the second year is almost identical with the regular second-year work of the course in Civil Engineering. The special extensions in sanitary work are developed in the third and fourth years. The sanitary subjects are set forth so as to cover in a thorough and comprehensive way those special fields occupied by the sanitary engineer of the present day. They include the sanitary treatment of water supplies and sewage with special work extended both by lectures and laboratory work into microscopical biology and bacteriology, standard laboratory methods in the sanitary administration of public water supplies, sanitary statistics and reports, drainage, heating and ventilation and the general principles of sanitary science, public health and hygiene. These sanitary specialties are of advanced character, covering the latest investigations in such special work as daily bacterial tests of potable water for public purposes, the extermination of mosquitoes and other disease-carrying insects, the improvement of public health conditions found in cities and towns, the drainage and sanitary treatment of lands and the sanitary administration of buildings and industrial establishments. A graduate, therefore, of this course is qualified to enter the practice of sanitary engineering in all its special fields.

SECOND YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
70	Botany 7	Growth and Character of Timbers	1	3
73	Chemistry 65	Quantitative Analysis	2	6
82	Drafting 5	Graphics		3
90	Math. 65	Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
105	Mineralogy 5	Minerals of Building Stones	2	3
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
		Total..	18	20
		Second Half Year		
74	Chemistry 76	Microscopical Analysis		3*
75	Chemistry 82	Industrial Chemistry	3	
82	Drafting 8	Structural Drafting		6
83	Elect. Eng. 2	Electrical Engineering	2	
87	Geology 18	General Geology	3	3†
110	Mechanics 102	Analytical Mechanics	5	
90	Mech. Eng. 14	Steam Power Machinery	3	
101	Metallurgy 134	Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physics Laboratory		3
112	Shop Work 16	Bench and Machine		3
		Total..	18	16

*February and March—Microscopical Analysis equivalent to 1 hour.
†April and May—Geology equivalent to 1 hour.
SUMMER WORK: Practical Surveying C.E. 25s.—5 weeks.

THIRD YEAR

See Page	Name of Course	Description of Course	Hours per week Lect.	Lab'y
		First Half Year		
74	Chemistry 41	Organic Chemistry	2	
76	Chemistry 79	Sanitary Bacteriological Analysis	2	6
72	Civil Eng. 21	Roads, Streets, and Pavements	1	
77	Civil Eng. 51	Railroad Surveying	2	3
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials Testing		3
78	Civil Eng. 59	Sanitary Treatment of Water Supply and Sewage	2	
78	Civil Eng. 61	Theory of Trusses	2	3
		Total..	16	18
		Second Half Year		
74	Chemistry 78	Sanitary Biological Analysis	2	3
77	Civil Eng. 52	Railroad Surveying	3	3
77	Civil Eng. 54	Resistance of Materials		3
78	Civil Eng. 58	Masonry Structures	3	3
78	Civil Eng. 62	Graphic Statics	2	3
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
97	Mech. Eng. 78	Kinematics	3	
		Total..	16	18

SUMMER WORK: Hydrographic Surveying, C. E. 26S and Limnology C. E. 26 a S—5 weeks. Railroad Surveying Practice, C. E. 71S—4 weeks.

FOURTH YEAR

		First Half Year		
74	Chemistry 179	Analysis of Water and Sewage	1	6
78	Civil Eng. 57a	Sanitary Statistics and Reports }		
78	Civil Eng. 57b	Drainage of Marshes and Lowlands }	2	
79	Civil Eng. 75	Hydraulics	3	
79	Civil Eng. 85	Foundations	2	
79	Civil Eng. 87	Bridges, Roofs and Buildings	2	3
80	Civil Eng. 89	Railroad Engineering	3	3
80	Civil Eng. 97	Water Supply and Irrigation Eng.	3	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
95	Mech. Eng. 63	Hydraulics Laboratory		3
		Total..	18	15
		Second Half Year		
74	Chemistry 180, or }	Sanitary Analysis	1	6 }
80	Civil Eng. 90 }	Railroad Engineering	3	3 }
80	Civil Eng. 94	Sewers, and River and Harbor Imp.	2	
80	Civil Eng. 96	Principles of Hygiene, Sanitary Science and Public Health	3	
81	Civil Eng. 100	Thesis		6
84	Elect. Eng. 76	Alternating Current Laboratory	1	3
89	Law 2	Business Law	2	
97	Mech. Eng. 82	Heating and Ventilation	2	
97	Mech. Eng. 76	Standard Tests	1	3
		Total..	15	15 or 18

ELECTRICAL ENGINEERING

General Statement

The prescribed course leading to the degree of Electrical Engineer requires four years for its completion, and is designed for the education of those who intend to practice the profession of Electrical Engineering, either as engineers, managers, experts in industrial enterprises or as teachers in colleges or technical schools.

The instruction comprises the important branches of theoretical and applied electricity, also the fundamental and collateral subjects, which have been found by experience to be required by the electrical engineer, as, for example, mathematics, physics, chemistry, drawing, mechanical engineering, including boilers, gas producers, engines, turbines, hydraulic developments, transmission devices and shop work, also such general engineering subjects as construction in wood, masonry, iron and steel.

The graduate in Electrical Engineering is accordingly provided not only with a thorough knowledge of the principles and applications of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for the demands likely to be made upon him in connection with the practice of his profession.

The instruction is by lectures and recitations as well as by laboratory, work-shop and drawing-room practice, with periodic visits to the numerous and important electrical factories, power stations and other establishments in and about New York City.

Equipment

The offices, laboratories, museums and lecture rooms of the Electrical Engineering Department are in the southern portion of the Engineering Building. The laboratories located in the basement contain direct and alternating current machinery and apparatus. The smaller machines are mounted upon heavy tables, thus raising them to a convenient height and affording space for instruments and note-books. To further simplify the work, the machines have been assembled into unit sets, a motor being provided for each generator, so that the experimental work of one squad of students is entirely independent of that of other squads.

The direct current laboratory contains constant potential and constant current generators, motor-dynamos, as well as various types of stationary and railway motors, aggregating forty machines ranging in capacity from 1 to 35 kilowatts and of standard voltages from 115 to

550. Two 10 and two 5 k.w. generator sets with complete switchboards, carrying many measuring instruments enable various experiments to be performed by the students on the parallel operation of generators. The constant current equipment includes a dynamo, standard switchboard and series lamp circuits. A working standardization equipment for the calibration of all measuring instruments is installed in this laboratory, and prior to any tests the students are required to check their various instruments. About eighty electrical measuring instruments are employed in this laboratory, comprising ammeters and voltmeters with various scale ranges, also speed indicators, transmission and absorption dynamometers. This laboratory is provided with a set of machine and hand tools employed in the repair of the various pieces of apparatus.

The alternating current apparatus, located in the adjoining room, comprises one single-phase alternator of 10 k.w. capacity and two three-phase alternators of 10 and 45 k.w. capacity, respectively; two 10 kilowatt synchronous motors and rotary converters operative on single-phase or two-phase circuits; two single-phase and four polyphase induction motors varying in capacity from 1 to 10 horse-power; constant potential transformers of various capacities; phase transformers for converting two-phase to three-phase currents and *vice versa;* a constant current transformer equipment of 5 kilowatts capacity with its control board, circuits and lamps; an induction regulator of 5 kilowatts and a mercury arc rectifier of the same capacity. Each of the various alternators is provided with its own driving motor, so that the speed, voltage and frequency may be altered as desired. This laboratory equipment includes a complete switchboard for the operation, control, and testing of the rotary converters used as such or as alternators; also a special polyphase circuit measuring board and about fifty instruments for the measurement of alternating voltage, current and power. The alternating current ammeters and voltmeters are of various capacities, ranging from fractional values up to 2,000 amperes and 600 volts respectively, also wattmeters up to 1,200 kilowatts range. The instrument equipment further includes several frequency indicators, synchronizers and power factor meters as well as a complete oscillograph and an ondograph for the determination of wave forms, phase relations, etc.

The lecture rooms are provided with direct-current, single-phase and polyphase electrical circuits and projection lanterns so that the lectures may be accompanied by experimental demonstrations and illustrations. The museum contains many pieces of apparatus and parts of machines used in connection with the lectures, such as specimens of pole line insulators, conduit material, rail sections, rail bonds, insulated cables and materials employed in transmission line and electric railway construction. Also various pieces of apparatus employed in telegraphy

and telephony; forms of storage battery plates, samples of products obtained by electro-chemical actions, elementary electrical apparatus, etc.; pieces of electrical machinery, such as armature laminations, field and armature coils, commutator sections, brush holders, brushes, insulating materials; small models of various types of generators and motors; numerous forms of incandescent and arc lamps, lamp mechanisms, carbons and electrodes; lightning arresters, line protecting devices and measuring instruments.

On the third floor of the building are located the large instrument laboratory, the departmental drawing-room and the studies of the officers. The laboratory contains tables upon which the various instruments are permanently set up, ready for use. These include many different forms of galvanometers, three ampere balances with scale ranges from .01 to 600 amperes, two dynamometers with ranges of 1 to 200 amperes respectively, a Standard Weston laboratory voltmeter having a range from .01 to 750 volts and a Standard Weston laboratory millivoltmeter with a set of shunts reading up to 500 amperes, Westinghouse precision watt and voltmeters and two very accurate potentiometers. The equipment further comprises apparatus for the exact measurement of resistance, inductance, permeability, hysteresis, and magnetic leakage. This laboratory is supplied with electrical energy from special sources, so that fluctuations do not cause uncertainty in the various measurements. For the direct current work special storage batteries supply potentials up to 250 volts and others have current capacity of 1,000 ampere-hours. For tests requiring small values of alternating currents a special alternator is operated. This laboratory also contains high tension testing apparatus, consisting of two 50,000 volt transformers of 5 and 10 kilowatts capacity respectively, two 10,000 volt transformers of 5 and 10 kilowatts respectively, and one 5,000 volt transformer of 5 kilowatt output. These transformers are supplied with necessary protective and measuring devices and all are designed for operation on 60 cycle circuits. This instrument laboratory is also equipped with several forms of standard integrating and recording watt-hour meters employed in connection with the standardization of consumers' electric meters for the Department of Water Supply, Gas, and Electricity of the City of New York.

The Photometric Testing Laboratory of this Department is equipped with a stationary type Lummer-Brodhun screen photometer for incandescent lamp testing, a Bunsen screen photometer with a meter prover for gas light testing, a Sharpe-Millar and a Weber photometer, which are adaptable to arc lamp testing or for the determination of general illumination, also a mirror photometer, to be used in the determination of the intensity of illumination of large luminous sources.

ELECTRICAL ENGINEER

The objects for which the regular four years' course in Electrical Engineering is designed and the education which it is intended to give are fully set forth in the "General Statement" of the Electrical Engineering Department.

The actual curriculum, including the various requirements which must be fulfilled in order to obtain the E. E. degree, are given in the following list of studies for each year, the character of each subject or requirement being explained more fully in the Departmental Statement referred to. The first two years of the course are devoted to the fundamental subjects, including mathematics, physics, chemistry, mechanics, drawing and certain electrical and mechanical engineering subjects which are elementary or introductory in character.

These fundamental and introductory subjects are intended to lay a broad and substantial foundation upon which the more specialized professional instruction of the third and fourth years is based. Even in these later years theoretical subjects, such as thermodynamics and electro-mechanics, are included and given most careful attention.

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
73	Chemistry 65	Quantitative Analysis	2	6
82	Drafting 5	Graphics		3
90	Mathematics 65	Calculus	5	
90	Mech. Eng. 13	Steam Power Machinery	3	
109	Phys. Educ. B	Gymnasium		2
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
110	Physics 55	Physical Measurements	2	
112	Shop Work 13	Machine Work		3
		Total..	17	17
Second Half Year				
75	Chemistry 82	Industrial Chemistry	3	
82	Drafting 6	Graphics		3
82	Drafting 8	Structural and Machine Drawing		6
83	Elect. Eng. 2	Elements of Dynamo Electric Mach'y	3	
90	Mech. Eng. 14	Steam Power Machinery	3	
110	Mechanics 102	Analytical Mechanics	5	
101	Metallurgy 134	Metallurgy of Iron and Steel	2	
109	Phys. Educ. B	Gymnasium		2
110	Physics 44	Physical Laboratory		3
112	Shop Work 14	Machine Work		3
		Total..	16	17
Summer memoir.				

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
77	Civil Eng. 53	Resistance of Materials	5	3
77	Civil Eng. 53	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 77	Hydraulics	2	
84	Elect. Eng. 101	Generator and Motor Practice	3	
86	Elect. Eng. 173	Direct Current Laboratory		6
90	Mech. Eng. 17	Engineering Thermodynamics	2	
93	Mech. Eng. 41	Machine Design	1	3
110	Mechanics 105	Thermodynamics	2	
111	Mechanics 107	Theory of Electricity and Magnetism	2	
		Total..	17	15
		Second Half Year		
82	Economics 2	Economics	3	
83	Elect. Eng. 52	Design of Direct Current Machinery	2	3
85	Elect. Eng. 104	Electrical Distribution	3	
86	Elect. Eng. 174	Direct Current Laboratory	1	6
90	Mech. Eng. 18	Engineering Thermodynamics	2	
92	Mech. Eng. 36	Kinematics of Machinery		6
97	Mech. Eng. 76	Standard Tests	1	3
111	Mechanics 108	Theory of Electricity and Magnetism	3	
		Total..	15	18
		Summer memoir.		

FOURTH YEAR

		First Half Year		
76	Chemistry 183	Electrochemistry	2	3
84	Elect. Eng. 103	Electric Motors	3	
85	Elect. Eng. 105	Alternating Current Engineering	3	
85	Elect. Eng. 109	Telegraphy	1	
86	Elect. Eng. 175	Alternating Current Lab.	1	6
86	Elect. Eng. 177	Instrument Laboratory	1	6
94	Mech. Eng. 53	Steam Turbines	2	
97	Mech. Eng. 77	Standard Tests	1	3
111	Mechanics 109	Theory of Alternating Current Machines	4	
		Total..	18	18
		Second Half Year		
83	Elect. Eng. 54	Design of Alt. Current Machinery	2	3
84	Elect. Eng. 98	Graduation Thesis (Optional)		
85	Elect. Eng. 106	Electric Plants	2	
85	Elect. Eng. 108	Plant Inspection	1	3
85	Elect. Eng. 110	Telephone	1	
85	Elect. Eng. 112	Electric Railways	2	
86	Elect. Eng. 176	Alternating Current Laboratory	1	6
95	Mech. Eng. 56	Hydraulic Turbines Installations	1	
95	Mech. Eng. 60	Hydraulic Laboratory		3
96	Mech. Eng. 72	Gas Power Machinery	2	3
111	Mechanics 110	Theory of Electrical Circuits	3	
111	Physics 52	Conduction of Electricity in Gases	1	
		Total..	16	18

MECHANICAL ENGINEERING

General Statement

The regular four-year course, leading to the degree of Mechanical Engineer, offers a thorough basic training in the design, construction, manufacture and operation of all classes of standard and special machinery, and their economic application to railroads, ships, mills, shops, factories and power plants, as well as in the technical and executive management of the manufacturing and transportation industries. To this end the course of instruction is as broad as is consistent with the directness of its purpose. The Mechanical Engineer must not only be grounded in the fundamental scientific basis of his profession, and so trained as to be capable of applying this to both the technical and commercial aspects of industrial problems, but his immediate usefulness upon graduation demands that a considerable portion of the instruction be concerned with the practical application of the principles taught.

The course begins with a thorough training in mathematics, physics and chemistry as a foundation for the appropriate technical work, which is developed along several parallel lines. Applications of these fundamental sciences to the physical properties of the materials of construction, especially the metals and their practical manipulation, lead through the courses in metallurgy, mechanics, resistance of materials, shop processes, the materials testing laboratory, drafting and kinematics to the principles of design, which are fixed by application to the design of machinery for the execution of any sort of process in which machinery is either absolutely essential or more economical than corresponding hand execution of the same process. The principles underlying the performance of machinery are developed by courses in thermodynamics, mechanics and hydraulics with experimental laboratory demonstration and are fixed by analysis of machinery for steam, gas and water power, pumping, compressing, refrigerating, mechanical handling of materials and their most important applications. The instruction in the performance, design and manufacture of machines and power units in the class-room and laboratory, supplemented by visits to power plants and factories, is the basis of the work on the design of plants and mills.

Throughout the instruction the student is thrown as much as possible on his own resources, encouraged to use such knowledge as he possesses, to read standard authorities and to make comparisons between the existing data on various subjects and with the results of theoretical computations. In the experimental work special stress is laid upon this as a means for the development of that initiative, execu-

tive ability and spirit of investigation so necessary for the successful practice of the profession, which is one long series of new problems demanding solution. The commercial and industrial phases of the technical subjects are dwelt upon throughout the entire course of instruction, and particular attention is given to labor and cost systems, works management, economy of manufacture and of power generation, economics and industrial law.

To insure a close contact between the work of the department and the practice of the profession, recognized experts are invited to give lectures on their particular subjects, the regular officers of the department attending and subsequently holding recitations and examinations.

For a list of special lecturers and their subjects see pages 9-12.

In addition to these regular lecturers, a list of non-resident lecturers, who deliver one or more lectures to the students on the work in their respective engineering fields will be found on pages 9-12.

The overlapping of the Mechanical Engineering and Electrical Engineering professions makes it desirable that the Mechanical Engineer shall be thoroughly conversant with the ordinary problems of the Electrical Engineer in the generation and distribution of electric current, the characteristics of electrical machinery, and the design and installation of electrical plants. To this end students in this course receive instruction in the department of Electrical Engineering covering these subjects.

Graduate work in Mechanical Engineering is offered to students who have successfully completed the undergraduate course. This graduate work includes the more difficult applications of mechanics and thermodynamics to questions of engineering, as well as special investigations in design, experimental research, and the development of new processes of manufacture. Courses are also offered to students in other departments covering such instruction in Mechanical Engineering as may properly assist in the practice of their respective professions.

Equipment

Besides the usual offices, lecture rooms, drawing rooms and museum, the department is unusually well equipped with experimental laboratory facilities. These laboratories cover a floor space of some 18,500 sq. ft. and contain apparatus valued roughly at $75,000. A fairly full line of instruments for making simple measurements is always available for regular student work, and includes thermometers, pyrometers, barometers, simple and differential manometers, draft gauges, speed counters, tachometers, angular velocity meters, planimeters, Pitot tubes, water meters of piston, rotary and Venturi type, hook gauges, steam and gas meters, steam, gas, coal and oil calorimeters, flue gas analysis apparatus,

scales for weighing and measuring, transmission dynamometers, Prony brakes, indicators of all types, pressure and vacuum gauges, anemometers, mercury columns, and calibrating apparatus for all instruments. Besides these measuring devices there is a large number of pieces of special apparatus for various purposes, such as the testing of carburetors, pressures due to explosion of gas mixtures, rate of flame propagation in explosive mixtures, pressure and temperatures of vaporization of liquid fuels, loss of head in steam, air and water pipes, condensation of steam in pipes, flow of steam or water through orifices and turbine nozzles, capacity of steam traps, flash, chill, density, viscosity and carbonization of oils, friction of bearings, losses in power transmission. These various instruments and pieces of apparatus are grouped and used in connection with a considerable number of machines of standard form. They include a standard gauge Vauclain compound locomotive, mounted on friction wheels equipped with dynamometers. This locomotive is so erected that it can be operated with its own steam, line steam or compressed air, the exhaust passing through an induced draft fan separately driven by a small steam engine. A Reynolds Allis-Corliss triple expansion engine, double eccentric type, is equipped to operate condensing and non-condensing, and is fitted with reheating receivers and may be operated with line steam or high pressure steam from the locomotive boiler. The Corliss engine is tandem connected to three air cylinders, equipped with Gutermuth flap valves, operating three-stage with water intercoolers. A cross compound steam, two-stage air compressor of the Ingersoll-Sargent type operates in parallel with the other air compressor and with a Westinghouse simple air pump with complete air brake equipment. There is also a belt and a steam driven fan for fan investigations, together with belt and steam driven centrifugal pumps for corresponding investigation on centrifugal action of water. Besides the steam engines mentioned there are also a McIntosh and Seymour automatic; Sweet straight-line simple engine, besides some smaller reciprocating units, and a De Laval steam turbine, all piped to condensers for efficiency tests on steam, wet, dry or superheated by a Foster superheater separately fired. The steam used by the engines and pumps is measured by any one of three surface condensers, Wheeler, Worthington, Allis, each with its own air and circulating pumps. The steam equipment includes also typical injectors, steam traps, feed water heaters, separators, reducing valves, safety valves, back pressure valves and other ordinary steam auxiliaries and specialties. The hydraulic work is well provided for by two large 20,000-lb. measuring tanks, fitted with swinging guide-buckets for continuous flow measurements, receiving the discharge from all the hydraulic apparatus; rectangular and trapezoidal weirs, fitted to several weir tanks, of iron and wood, three impulse water wheels, one small turbine, one hydraulic ram, simple, single and duplex steam

pumps, direct acting and flywheel, single acting, direct acting triple expansion duplex, low pressure Worthington pump of large capacity and low head, separately steam driven centrifugal Lawrence pump, belt driven centrifugal pump, a high pressure pump and accumulator of the Worthington type for 1500 lbs., and a second for 5000 lbs. pressure. Several internal combustion engines, including the Nash, fitted to operate on various fuels, a Hornsby-Akroyd and a Mietz and Weiss oil engine, an Otto, an International Harvester, a boat engine are equipped for gas engine test and investigation work of great variety. From time to time other machines are secured for short periods of time for testing purposes. For the study of refrigeration there is installed a small Brunswick ammonia compression ice-making and refrigerating unit, motor driven, and a larger De La Vergne steam-driven, ice-making plant.

MECHANICAL ENGINEER

All the subjects leading to the degree of Mechanical Engineer are listed in the following table, together with the year and term in which they are given. The first two years are devoted to essential preparatory and fundamental subjects, mathematics, chemistry, physics, analytical mechanics and drawing which are co-ordinated with kinematics, elementary design, shop work and the elements of electrical and steam engineering. In the third year there are developed the basic principles of thermodynamics, resistance of materials and hydraulics, which are fixed in the mind of the student by drill in the drafting room by design courses, in the laboratory by experiments and tests and in class by analysis of standard mechanical and electrical machinery. The fourth year is devoted to a detailed treatment of gas and steam engine design, standard water turbine characteristics and the essential relations between units constituting power plants and factories. Special attention is here paid to the economics of mechanical engineering by courses in industrial law, economics and works management. Throughout the course the aim is to develop clear conceptions of underlying principles, habits of independent thought and orderly mental procedure applicable to any sort of Mechanical Engineering problems rather than to the memorization of isolated facts. The training given not only fits the student to take up the design of machinery and the perfection of processes of doing things by mechanical means, but also to take ultimately a leading place in the management of the manufacturing and transportation industries.

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
82	Drafting 7	Structural Drafting		
90	Mathematics 65	Calculus		3
90	Mech. Eng. 11	Steam Power Machinery	5	
92	Mech. Eng. 35	Kinematics	3	
94	Mech. Eng. 59	Empiric Design		3
109	Phys. Educ. B	Gymnasium	2	3
110	Physics 5	Electricity		2
110	Physics 43	Physical Laboratory	5	
112	Shopwork 1	Pattern Making		3
				6
		Total..	15	20
Second Half Year				
75	Chemistry 82	Industrial Chemistry		
83	Elect. Eng. 2	Elements of Electrical Engineering	3	
90	Mech. Eng. 12	Steam Power Machinery	2	
92	Mech. Eng. 36	Kinematics	3	3
110	Mechanics 102	Analytical Mechanics		3
101	Metallurgy 134	Iron and Steel	5	
109	Phys. Educ. B	Gymnasium	2	
110	Physics 44	Physical Laboratory		2
112	Shopwork 2	Moulding and Foundry Practice		3
112	Shopwork 12	Forging		3
				6
		Total..	15	20

SUMMER WORK: Shop Work 108. 125 hours in College shops; Mech. Eng. 94s. 6 weeks practical work in shops and drafting rooms of manufacturing establishments, with report. A total of 9 weeks.

THIRD YEAR

See Page		*First Half Year*	Hours per week: Class	Hours per week: Lab'y & Draft'g.
77	Civil Eng. 53	Resistance of Materials	5	3
83	Elect. Eng. 73	Direct Current Laboratory		3
84	Elect. Eng. 101	Dynamo and Motor Practice	2	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
92	Mech. Eng. 31	Standard Tests	1	3
93	Mech. Eng. 39	Machine Design	3	3
110	Mechanics 105	Thermodynamics	2	
112	Shopwork 11	Machine Shop		6
		Total..	15	18
		Second Half Year		
77	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
79	Civil Eng. 78	Hydraulics	2	
85	Elect. Eng. 104	Electric Distribution	3	
90	Mech. Eng. 18	Engineering Thermodynamics	2	
92	Mech. Eng. 32	Standard Tests	1	3
93	Mech. Eng. 40	Machine Design		9
94	Mech. Eng. 54	Shop Processes	2	
96	Mech. Eng. 64,	Air Machinery	2	
96	Mech. Eng. 66,	Elevators and Conveyors	1	
96	Mech. Eng. 70,	Pumping Machinery	2	
95	Mech. Eng. 60	Hydraulic Laboratory	1	3
102	Metallurgy 156	Metallographic Laboratory		
		Total..	16	18

SUMMER WORK: Mech. Eng. 96s. 6 weeks practical work in power plant, with report

FOURTH YEAR

		First Half Year		
84	Elect. Eng. 103	Electric Power	2	
85	Elect. Eng. 105	Electrical Distribution	2	
91	Mech. Eng. 19	Engine Design	3	6
91	Mech. Eng. 21	Gas Power	4	3
91	Mech. Eng. 25	Steam Power	2	3
92	Mech. Eng. 33	Standard Tests	2	3
93	Mech. Eng. 45	Hydraulic Turbines	3	
		Total..	18	15
		Second Half Year		
82	Economics 2	Economics	3	
84	Elect. Eng. 76	Alternating Current Laboratory	1	3
89	Law 2	Business Law	2	
91	Mech. Eng. 20	Engine Design	3	6
91	Mech. Eng. 26	Steam Power	2	6
94	Mech. Eng. 50	Steam Turbines	3	
94	Mech. Eng. 52	Organization and Management	3	
		Total..	17	15

CHEMISTRY

General Statement

The regular four-year courses of instruction herein shown are designed for the education of professional chemists who intend to devote their lives to the practice of this profession, either as teachers in colleges and scientific schools, or as chemists or managers in manufacturing and other industrial enterprises.

There are two courses offered, leading to the degrees of Chemist and Chemical Engineer respectively.

Equipment

In Havemeyer Hall the Chemical Department is provided with space for its museum, lecture-rooms, and laboratories, and every convenience has been furnished for both the instructors and students working in the general or special courses.

There are five chemical lecture-rooms, all fully supplied with apparatus and instruments, the desks being equipped with pneumatic troughs, gas, pressure, exhaust, and electricity. The large chemical lecture-room on the ground floor contains 348 seats.

The Chandler Museum of General Inorganic and Organic Chemistry and of the Chemical Arts, a large room occupying the whole left wing of the ground floor, contains the elements and all their more important compounds, inorganic and organic; materials and products illustrating the chemical arts, and numerous models, pictures, and diagrams.

The new William H. Nichols Laboratories for General Inorganic Chemistry and Qualitative Analysis, together with the rooms for instructors and for research, occupy the whole of one floor of Havemeyer Hall. They are fitted up in the most modern and complete way, with all the conveniences required for instruction and investigation.

The Quantitative Laboratory has eighty-eight desks. Attached to the main laboratory is a large, well-equipped balance-room, containing accurate balances, and special rooms, provided with apparatus for gas, water, food, and electrolytic analysis.

The Organic Laboratory has forty large desks, provided with gas, water, exhaust, and electricity, and has special rooms for balances, pressure ovens, and glass-blowing.

The Laboratory of Industrial and Engineering Chemistry, for the instruction of students in practical application and the solution of problems in connection with the chemical industries, is equipped for the manufacture of pure chemicals from their raw materials on a large scale, with batteries of steam evaporators, and with steam stills, centrifugals, filter presses, crushers, vacuum dryers, multiple effect evaporators, stills and general apparatus for industrial research. It includes

a textile and paper laboratory containing a calico printing machine, paper making machinery, etc., and the regular equipment for practical research. Connected with it is a photometer-room containing a new and complete outfit for the practical testing of illuminants.

A new Laboratory for Applied Electrochemistry has been provided. The equipment consists of special motor-dynamos, one of which furnishes direct current at low voltages to the students' desks for general electrolytic work; the other provides heavy alternating current to the electric furnace room; this room is furnished with all appliances for electric furnace work. The students' desks are fitted with special switchboards and measuring instruments, and the laboratory has been arranged for carrying on research work in all branches of electrochemistry.

The Laboratory of Physical Chemistry is well equipped with the most recent apparatus adapted to a wide range of experimental work in the branches of heat, light, and electricity as applied to chemical problems.

The Chemical Library in Havemeyer Hall is supplied with an extensive collection of chemical books and journals, and is open from 9.00 A.M. to 5.00 P.M., and during the session of the University from 8.00 to 11.00 P.M.

CHEMICAL ENGINEER

The course in chemical engineering, as will be seen, is designed to educate chemists with a sufficient amount of engineering to fit them to take charge of chemical industries which depend upon the application of engineering methods and appliances to the manufacture of chemical products. This requires a knowledge of mechanical engineering, electrical engineering, hydraulics, mechanical drawing, shopwork, etc., as well as a thorough knowledge of chemistry in all its branches.

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Organic Chemistry	2	
75	Chemistry 81	Industrial Chemistry	3	
73	Chemistry 163	Quantitative Analysis	3	12
90	Mathematics 65	Calculus	5	
105	Mineralogy 15	Determinative Mineralogy		3
110	Physics 5	Electricity	5	
110	Physics 43	Physical Laboratory		3
109	Phys. Educ. B	Gymnasium		2
		Total..	18	20
Second Half Year				
72	Chemistry 42	Organic Chemistry	2	
75	Chemistry 82	Industrial Chemistry	3	
73	Chemistry 164	Quantitative Analysis	3	12
83	Elect. Eng. 2	Elements of the Dynamo	2	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 16	Determinative Mineralogy		3
110	Physics 44	Physical Laboratory		3
109	Phys. Educ. B	Gymnasium		2
		Total..	15	20

SUMMER WORK: Chemistry 80a, 1 week. Shopwork 18s (8), 3 weeks in June or July.

THIRD YEAR

See Page		*First Half Year*	Hours per week Class	Lab'y
77	Chemistry 49	Organic Chemistry	2	9
72	Chemistry 83	Industrial Chemistry	3	
75	Chemistry 101	Advanced Inorganic	2	
70	Civil Eng. 53	Resistance of Materials	5	3
90	Mech. Eng. 11	Steam Power Machinery	3	
95	Mech. Eng. 59	Empiric Design	2	3
		Total..	17	15
		Second Half Year		
77	Chemistry 84	Food Chemistry	3	
79	Chemistry 102	Advanced Inorganic	2	
73	Civil Eng. 54	Resistance of Materials (Testing Lab.)		3
70	Civil Eng. 76	Hydraulics	2	
83	Elect. Eng. 4	Electric Distribution	2	
83	Elect. Eng. 72	Direct Current Laboratory	1	3
89	Law 2	Business Law	2	
90	Mech. Eng. 12	Steam Power Machinery	3	3
104	Metallurgy 182	Assaying	2	6
		Total..	17	15

SUMMER WORK: Chemistry 80b. Visits to Industrial Plants—2 weeks. Chemical Factory work with Report—6 weeks.

FOURTH YEAR

		First Half Year		
71	Chemistry 121	Physical Chemistry	3	
74	Chemistry 171	Organic Analysis	2	6
75	Chemistry 197	Chemical Factory Machinery	}	
98	Mech. Eng. 97	Mechanical Equipment of Chemical Factories	} 5	
90	Mech. Eng. 17	Engineering Thermodynamics	2	
93	Mech. Eng. 37	Machine Design	1	6
97	Mech. Eng. 77	Standard Tests	1	3
100	Metallurgy 101, 111	Introduction and Metallurgy of Copper	3	
101	Metallurgy 131	Iron and Steel	1	
		Total..	18	15
		Second Half Year		
75	Chemistry 88	Chemical Engin. Laboratory		9
71	Chemistry 122	Physical Chemistry	3	3
76	Chemistry 184	Practical Electro-Chemistry	2	3
75	Chemistry 198	Chemical Factory Organization	3	
90	Mech. Eng. 18	Engineering Thermodynamics	2	
97	Mech. Eng. 76	Standard Tests	1	3
101	Metallurgy 122	Metallurgy of Gold, Silver, Lead, Zinc	3	
		Total..	14	18

THE DEGREE OF CHEMIST

The course in chemistry includes not only all branches of theoretical, analytical, and industrial chemistry, but also collateral sciences, such as mathematics, mechanics, physics, mineralogy, metallurgy, electrical engineering, and drawing, which have been found by experience to be required by the professional chemist. It is the intention to provide the graduate not only with a thorough knowledge of the principles and practice of chemistry in all its branches, but with such a broad and liberal education in the collateral sciences as will prepare him for every demand that will be likely to be made upon him in connection with his profession or in the pursuit of investigation.

SECOND YEAR

First Half Year			Hours per week	
See Page			Class	Lab'y
72	Chemistry 41	Elementary Organic—Lecture Course	2	
75	Chemistry 81	Industrial Chemistry	3	
73	Chemistry 163	Quantitative Analysis	3	12
90	Mathematics 65	Calculus	5	
105	Mineralogy 15	Determinative Mineralogy		3
110	Physics 5	Electricity	5	
—	Physics 43	Physical Laboratory		3
109	Phys. Educ. B	Gymnasium		2
		Total..	18	20
Second Half Year				
72	Chemistry 42	Elementary Organic—Lecture Course	2	
75	Chemistry 82	Industrial Chemistry	3	
73	Chemistry 164	Quantitative Analysis	3	12
83	Elect. Eng. 2	Elements of Dynamo	2	
110	Mechanics 102	Analytical Mechanics	5	
105	Mineralogy 16	Determinative Mineralogy		3
—	Physics 44	Physical Laboratory		3
109	Phys. Educ. B	Gymnasium		2
			15	20

SUMMER WORK: Chemistry 80a.

THIRD YEAR

See Page			Hours per week Class	Lab'y
		First Half Year		
75	Chemistry 83	Industrial Chemistry	3	
70	Chemistry 101	Advanced Inorganic	2	
71	Chemistry 121	Physical Chemistry	3	3
74	Chemistry 171	Organic Analysis	2	6
74	Chemistry 175	Food Analysis	2	6
76	Chemistry 183	Industrial Electrochemistry	2	3
		Total..	14	18
		Second Half Year		
73	Chemistry 84	Food Chemistry	3	
75	Chemistry 88	Industrial—Laboratory Course		9
70	Chemistry 102	Advanced Inorganic Chemistry	2	
71	Chemistry 122	Physical Chemistry	3	
104	Metallurgy 182	Assaying	2	6
105	Mineralogy 10	Mineralogy and Crystallography	2	3
		Total..	12	18

SUMMER WORK: Chemistry 80b—Visits to Industrial Plants—2 weeks.
Chemical Factory work and Report—6 weeks.

FOURTH YEAR

		First Half Year		
75	Chemistry 89	Industrial Chemistry—Lab. Practice		3
72	Chemistry 141	Organic Chemistry—Advanced Course	3	
72	Chemistry, 43M	Organic Chemistry—Lab.		12
100	Metallurgy 101, 111	Introduction and Metal'gy of Copper	3	
101	Metallurgy 131	Iron and Steel	1	
—	Chemistry 225	Physical Chemistry } Electives, two to be taken.		
72	Chemistry 255	Organic Chemistry		
73	Chemistry 111	Theory of Inorg. Anal.	4	
—	Chemistry 153	Gen'l Org. Chem.		
		Total..	11	15
		Second Half Year		
72	Chemistry 142	Organic Chemistry—Advanced Course	3	
101	Metallurgy 122	Lead, Silver, Gold and Zinc	3	
	Thesis—			
71	Chemistry 226	Physical Chemistry } Electives, two to be taken.		
72	Chemistry 256	Organic Chemistry	4	
—	Chemistry 112	Theory of Inorg. Anal.		
—	Chemistry 154	Gen'l Org. Chem.		
—	Chemistry 218	Inorganic Chem.: Research—or }		
71	Chemistry 228	Physical Chem.: Research—or		
72	Chemistry 258	Organic Chem.: Research—or		15
73	Chemistry 268	Analytical Chem.: Research—or		
74	Chemistry 278	Food Chem.: Research—or		
76	Chemistry 288	Electro Chem.: Research		
		Total..	10	15

COURSES OF INSTRUCTION

Arranged Alphabetically by Departments

ASTRONOMY

***105—Geodesy.** 2 hours and evening visits to the observatory. Professor JACOBY.

Outline of general astronomy; theory of the celestial sphere, time, motions of the earth, the calendar. Spherical trigonometry. Theory of the method of least squares and geodetic triangulation adjustments. Trigonometric levelling and barometric hypsometry. Theory of the astronomic transit instrument, zenith telescope, and sextant. Reference book: Jacoby's *Astronomy.*

106—Geodesy. 1 hour and 1 laboratory period. Professor JACOBY.

The applications of spherical astronomy to geodetic surveying, and training in methods of accurate computation. Reference book: Doolittle's *Astronomy.*

107s—Geodetic Surveying. Professor JACOBY, with Assistants.

Summer Course in Practical Geodesy: Given at Camp Columbia, Morris, Conn.

The work consists in the development of a system of geodetic triangulation to include measurement of base line with Invar tapes, angles with microscope theodolites, adjustment of primary quadrilaterals by the method of least squares, together with measurement and computations for the location of secondary stations which furnish the triangulation for the hydrographic survey. See course C.E. 26S.

There is also included the use of the sextant for time and latitude, barometric hypsometry and trigonometric leveling; the level trier; the determination of latitude by zenith telescope, and longitude by star transit, chronograph, etc. A student organization consisting of chief engineer, chief computer, commissary of transportation, etc., attends to the details of administration under the direction of University instructors. Each student must submit computations, reports and record book.

Pre-requisite: Course C.E. 25S and Ast. 105-6.*

See special announcement of Summer Session at Camp Columbia. For fees and deposits see page 41.

Pre-requisite for all courses in Astronomy: Mathematics of first two years.

*In 1914-15 courses 105 and 106 will be combined into a single course, given during the second term in an abbreviated form, Professor Jacoby being absent on leave during the first term.

BOTANY

7—Growth and Character of Timber. 1 hour and 1 afternoon. Professor CURTIS and Mr. ALTENBURG.

Growth of the tree, character and arrangement of its tissues; relation of moisture to strength of timber; the deterioration, preservation, distribution and identification of lumber.

Second year for Civil and Sanitary Engineering students.

CHEMISTRY

The following courses in Chemistry are included in the programs of study of the Schools of Mines, Engineering and Chemistry. For other courses offered see the *Announcement of the Division of Chemistry.*

Inorganic Chemistry

3, 61 or 4, 62—General Chemistry and Qualitative Analysis. 5 hours class-room and 5 afternoons laboratory. Not offered in 1914-15.

Inorganic chemistry in advance of entrance chemistry and the theory and practice of qualitative inorganic analysis based upon the principles of modern chemistry.

Pre-requisite: Chemistry A or Entrance Chemistry.

101-102—Advanced Inorganic Chemistry. 2 lectures. Undergraduate section. Dr. ———

Descriptive inorganic chemistry and the application of the laws and theories of chemistry and of modern views to chemical problems.
Pre-requisite: Course 163.

Summer Courses

For details, see the *Announcement of the Summer Session.*

sA—General Chemistry. Elementary course for students beginning the study of chemistry. 5 hours classroom and 6 hours laboratory work per week. Mr. HAESELER.

s3C—Inorganic Chemistry, Sequel to entrance chemistry **A.** 5 hours classroom and 15 hours laboratory per week. Mr. LESLIE.

s61—Qualitative Analysis. 10 hours lectures and conferences, and 30 hours laboratory work a week. Mr. CALVERT and Assistant.

Extension Teaching, Evening Courses

For details see the *Announcement of Extension Teaching.*

eA—General Chemistry. 2 lectures, 1 recitation and 2 hours laboratory practice, counting as 4 points. Dr. NEISH.

Physical Chemistry

121-122—Physical Chemistry. 3 hours lectures and recitations during the entire year, and 15 afternoons, equivalent to 1 afternoon a week, laboratory during the first or second half-year. Professor MORGAN and Assistant.

A course treating of the states of aggregation, solution, and ions in analytical chemistry, thermo-chemistry, chemical mechanics, and electro-chemistry. Textbooks: Morgan's *Elements of Physical Chemistry,* and Ostwald's *Physico-chemical Measurements.*

Pre-requisite: Course 3 or 4 and 61 or 62, Physics 3-4-5 and Mathematics 64-65.

225-226—Physical Chemistry. 2 hours in lectures or conferences throughout the year. Professor MORGAN.

Designed for four-year students in the course of chemistry, selecting a thesis in physical chemistry.

228—Physical Chemistry—Research. 5 afternoons during the second half year, for students taking a thesis in physical chemistry. Professor MORGAN.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s138—Elementary Physical Chemistry. 5 hours. Professor MORGAN.

Research. The laboratory is open to properly qualified students for research under the direction of Professor MORGAN.

Organic Chemistry

41-42—Organic Chemistry, Introductory Lecture Course. 2 hours. Dr. FISHER.

Instruction given on such important classes of compounds as the hydrocarbons, alcohols, ethers, organic acids, fats, waxes, soaps, cyanides, sugars, carbohydrates, alkaloids, coloring matters, drugs, perfumes, and the like. The lectures will be liberally illustrated by material from the Chandler Chemical Museum. Text-book: Perkin & Kipping's *Organic Chemistry.*

Pre-requisite: Course 3-4 and 61 or 62. It is urged that, if possible, laboratory work, Course 43M, be taken with this course.

43M—Organic Chemistry, Introductory Laboratory Course. 4 afternoons. Drs. NELSON and FISHER.

A study of the typical methods for preparation and the typical reactions of the important classes of organic compounds. Text-book: Jones' *Laboratory Outline of Organic Chemistry.*

Pre-requisite: Courses 3 or 4 and 61 or 62. Pre-requisite or parallel: Course 41-42.

141-142—Organic Chemistry, Advanced Course. 3 lectures a week for one year. Professor BOGERT.

A discussion of the less common and of the more complicated groups of organic compounds, together with a study of the theoretical principles involved, presented in the form of select chapters from the field, and illustrated both by experimental demonstration and by material from the Chandler Chemical Museum and from the Organic Laboratory. Text-book: Cohen's *Organic Chemistry.*

Pre-requisite: Chem. 3 or 4, 21-22, 61 or 62, 41-42, Physics 3-4, and Pre-requisite or parallel 43M.

255-256—Organic Chemistry, Conferences. 2 hours. Professor BOGERT.

Presentation and discussion of recent important investigations in the field of organic chemistry.

Required in the second half-year, of all fourth-year students in the School of Chemistry selecting a thesis in organic chemistry. Pre-requisite or parallel: Course 141-142. Pre-requisite Chem. 3,61 or 4,62, 65 or 66, 41-42, 43M, 21-22, and Physics 3-4.

153-154—General Organic Chemistry. 2 hours. Dr. NELSON.

A review of organic chemistry, with special reference to the theory of the reactions of organic chemistry as viewed from the modern standpoint.

Pre-requisite: 41-42, pre-requisite or parallel 43M.

49—Organic Chemistry for Chemical Engineering Students. 2 lectures and 3 afternoons. Drs. NELSON and FISHER.

The study of organic compounds and reactions with particular reference to their relation to commercial products and manufacturing processes.

Pre-requisite: Course 3,61 or 4,62, 41-42 or its equivalent. Required of all third-year chemical engineering students.

258—Organic Chemistry, Research. 5 afternoons during the second half-year for students taking a thesis in organic chemistry. Professor BOGERT and Dr. NELSON.

Summer Courses

For details, see *Announcement of the Summer Session.*

s41 or 42—Organic Chemistry, Elementary Lecture Course. 5 hours. Dr. FISHER. Equivalent to 41 or 42.

s43 or 44—Organic Chemistry, Laboratory Course. Dr. FISHER and Assistant. s43-44 is equivalent to 43M.

Research. The laboratory is open to properly qualified students for research under the direction of Dr. NELSON.

Analytical Chemistry

65—Quantitative Analysis, Inorganic, Short Course. 2 hours and 2 afternoons. Dr. BARRY.

The analyses included in this course are: Magnesium sulphate, potassium alum, coal, iron ore, copper, zinc, alkalimetry, acidimetry, and flue gas.

Pre-requisite: Courses 3 or 4 and 61 or 62.

66—Quantitative Analysis, Inorganic. 3 hours and 4 afternoons. Mr. FALES.

The analyses included in this course are: Magnesium sulphate, iron-ammonium alum, coal, iron ore, pig iron, zinc ore, limestone, slag, copper and lead ores, and flue gas.

Pre-requisite: Courses 3 or 4 and 61 or 62.

163-164—Quantitative Analysis. 163—3 hours and 4 afternoons. Professor BEANS.

The classroom work includes not only the methods applied in the laboratory, but discussions of quantitative separations from a theoretical standpoint, and chemical calculations.

The analyses included in this course are: Magnesium sulphate, sodium or other chloride, potassium alum, iron ammonium alum, coal, iron ore, pig iron, spiegel, limestone, ores of zinc, copper, nickel, lead, arsenic, alloys, rocks, gas analysis, etc.

Pre-requisite: Courses 3 or 4 and 61 or 62.

111-112—Theory of Inorganic Analysis. 2 hours. Professor BEANS.

A systematic study of the reactions and the theory of the separation and determination of the elements, including the rare elements.

Pre-requisite or parallel: Chemistry 101-102, 121-122, 163-164.

268—Analytical Chemistry, Research. 5 afternoon during the second half year for students in the course of Chemistry, who elect thesis work in inorganic analytical chemistry. Professor BEANS.

Summer Courses

For details see the *Announcement of the Summer Session.*

s66—Quantitative Analysis. 5 lectures and 30 hours laboratory work weekly. Professor BEANS and Assistant.

s164—Quantitative Analysis, Advanced. 5 lectures and 30 hours laboratory work weekly. Professor BEANS and Assistant.

Food Chemistry

84—Food Chemistry. 3 hours. Professor SHERMAN and Mr. THOMAS.

The general principles of food chemistry and food legislation and the chemical technology and control of the more important food industries; milk and its products; meat products; edible fats and oils; grain products; starch, glucose, sugar; fruit products; fermentation; etc.

Pre-requisite: Chemistry 3 or 4 and 81-82 or 41-42.

171—Organic Analysis. 2 hours and 2 afternoons. Professor SHERMAN and Mr. THOMAS.

The lectures include general and industrial organic analysis, fertilizer analysis and inspection, examination of drinking water. Special attention is given to the interpretation of the analytical results. Text-books: Sherman's *Methods of Organic Analysis* and Mason's *Examination of Water*.

The analyses included in this course are: Acidimetry and alkalimetry, alcohol, sugars, lubricating and other industrial oils, soap, fertilizers, and the sanitary analysis of water.

Pre-requisite: Chemistry **41-42** and **161-162**.

175—Food Analysis. 2 hours and 2 afternoons. Professor SHERMAN and Mr. THOMAS.

The class-room work of this course includes a discussion of the descriptive and analytical chemistry of the principal constituents of foods, and some of the more important enzymes connected with the utilization of foods, as well as the analysis of commercial food products. Special attention is given to the interpretation of the results of food analysis in relation to official standards of composition and purity. Text-book: Sherman's *Methods of Organic Analysis*.

The analyses included in this course are: Sugars, starches, cereals and bread-stuffs, edible oils, butter, milk, and food preservatives.

Pre-requisite: Chemistry **41-42** and **161-162**.

278—Food Chemistry, Research. 5 afternoons during the second half-year for students taking a thesis in Food Chemistry. Professor SHERMAN.

Summer Courses

For details, see the *Announcement of the Summer Session.*

S175—Food Analysis. Professor SHERMAN and Mr. THOMAS.

S176—Chemistry of Food and Nutrition. 3 hours. Professor SHERMAN. (Will be accepted as equivalent to Chemistry **84**.)

Research. The laboratory is open to properly qualified students for research, in organic analytical chemistry or the chemistry of foods, under the direction of Professor SHERMAN.

Sanitary Analysis

76—Microscopical Analysis. Laboratory and conference. 1 afternoon a week during February and March. Mr. BUSWELL.

Construction, use and care of the microscope. Examination and identification of common fibres, starches, spices, yeasts and other objects of economic importance. Common adulterants. Measurement of sand grains, micro-organisms, etc.

Pre-requisite: Chemistry **65**.

78—Sanitary Bacteriological Analysis. 2 hours lectures and 2 afternoons laboratory work, second half-year. Mr. BUSWELL.

Practical instruction in bacteriology and hygiene. A short course for sanitary engineering students.

Pre-requisite: Chemistry **65, 76**.

79—Sanitary Biological Analysis. 2 hours and 1 afternoon laboratory a week, first half-year. Mr. BUSWELL.

General principles of biology, biological activity-function, metabolism, symbiosis, etc.; special biology-unicellular animals and plants—causes of tastes, odors, and turbidity in drinking water.

Pre-requisite: Chemistry **65, 76**.

179—Analysis of Water and Sewage. 1 hour and 2 afternoons, first term. Mr. BUSWELL.

Physical, chemical, microscopical and bacteriological methods.

180—Sanitary Analysis. Advanced methods and special problems. Second term, 1 hour and 2 afternoons. Mr. BUSWELL.

Industrial Chemistry

81-82—Industrial Chemistry, General. 3 hours lectures. Professors WHITAKER and METZGER and Instructor.

Air; water; sulphur; sulphuric acid; nitric acid; hydrochloric acid; alkali industries; potash; artificial gases and natural gas; petroleum and its products; cement; paints and varnishes; soaps; ceramics; glass; explosives; fuels; structural materials.

Pre-requisite: Courses Chemistry 3 or 4 and 61 or 62.

83—Industrial Chemistry, Advanced Course. 3 hours. Professor METZGER and Assistant.

Textile; tanning; glue and gums; India rubber and plastics; celluloid; artificial fibers; paints, oils, varnishes; paper, etc.

Pre-requisite: Courses Chemistry 3 or 4 and 81-82 and 41 or 42.

88—Industrial Chemistry, Laboratory Practice. 3 afternoons. Professors WHITAKER and METZGER and Instructor.

Fourth-year students in Chemical Engineering.

89—Industrial Chemistry, Textile and Dye Chemistry. 1 afternoon. Professor METZGER and Assistant.

Special applications: Textile industry, vegetable and animal fibres, bleaching, dyeing, and calico printing.

Pre-requisite: Course 3 or 4, 41 or 42.

197—Chemical Factory Apparatus and Machines. 5 hours. Professors WHITAKER and THOMAS.

To cover the construction and use of the apparatus and machinery of chemical factories.

198—Chemical Factory Management. 3 hours. Professor WHITAKER.

Relations of the chemist to the various phases of making and marketing chemical products. Sales organization and methods; transportation of products and materials; purchase of supplies; warehousing and stocks; manufacturing organization; equipment; process; operation; cost keeping and accounting; process improvements; product improvements; factory economics; labor; insurance; fire and accident protection; finance; administration.

80a—Factory Inspection. Professors WHITAKER and METZGER and Instructor.

Visiting and inspection of chemical works of special interest in and near New York City, such as gas works, petroleum refineries, paint and varnish factories, soap and candle works, and plants for the purification of water and sewage.

Required of all second-year students in the courses of chemistry and chemical engineering. The visits to factories are made during the weeks following the final examinations.

80b—Summer Factory Excursion Work and Report. Professors WHITAKER and METZGER and Instructors.

Two weeks is devoted to a study of industrial plants in New York and neighboring cities. Students will also be required to work at least six weeks in a chemical factory or laboratory or in some position approved by the instructor. Full report on this requirement will be made to the instructors at the conclusion of the work.

Summer Courses

For details, see the *Announcement of the Summer Session.*

s81—Industrial Chemistry, General. 5 lectures per week. Dr. NEISH.

Electro-Chemistry

181-182—Practical Electro-Chemistry. 10 hours. Professor TUCKER.

Electroplating, influential factors in electrolysis, the use of diaphragms, electrolysis of fused salts, electrolytic preparations, metal refining, electric furnace practice, and preparation of carbides, silicides, etc., measurement of high temperatures.

Pre-requisite: Courses 3 or 4, 61 or 62, 65.

183-184—Industrial Electro-Chemistry. 2 hours and 14 afternoons. Professor Tucker.

The applications of electrolysis and the electric furnace to the production and purification of chemicals and metals. Illustrated by short laboratory course.

Pre-requisite: 3 or 4, 65.

288—Electro-Chemistry, Research. 5 afternoons during the second half-year for students taking a thesis in electro-chemistry. Professor TUCKER.

CIVIL ENGINEERING

2—Theory of Surveying. Lectures and recitations, 2 hours. Professor LOVELL, Mr. FINCH, Mr. ———.

Methods of measuring angles and distances. Cumulative and compensating errors, and corrections to be applied. Limits of precision. Use, care, and adjustment of the engineer's transit, level, and compass. Magnetic declination and variation. Local attraction. Relocation of old lines by compass bearings. Erroneous standards. Surplus and deficiency. Significance of monuments. Traverses; computations of area and error of closure. Laying out and dividing up land. System of public land surveys. Topographic surveys; transit stadia and plane table methods. Triangulation. City surveying, subdivision and resurveys. Interpretation of deed descriptions. Text-book: Tracy's *Plane Surveying.*

15S—Surveying between the First and Second Years. Field work and office work. 5 weeks. 4 surveys. Mr. FINCH and Assistants.

Survey 1 includes pacing and chaining, ranging out lines, contouring with hand level, mapping. *Survey 2* consists of the adjustment of the level and in running a line of differential levels. Note book and report. *Survey 3* consists of the adjustment of the transit, angle reading by repetition, determination of stadia constant, observations to determine reliability of the compass, the survey of a closed field or farm, measuring the boundary lines by steel tape and the angles or directions by transit and locating the principal topographic details by stadia. Notebook, computation of area and map. *Survey 4* consists of repetition traverse of a closed field, distances being measured by steel tape corrected for catenary, pull, and temperature. Determination of magnetic declination by observation on Polaris.

Pre-requisite: 2.

21—Highway Engineering. 1 hour. Professor LOVELL.

Road resistances—Design, construction, maintenance and repair, of Dirt, Gravel, Broken Stone and Miscellaneous Roads—Street Location—City pavements—Belgian and Granite Block, Brick, Asphalt and Wooden Block—Foundations—Grades—Drainage, Specifications. Reference and text-book: *Roads and Pavements,* Baker.

23—Theory of Railroad Surveying. 2 hours and 1 afternoon. Professor LOVELL and Mr. FINCH.

An abridged course, for students in Mining Engineering, covering the same subjects as are taken in Course 51-52.

Pre-requisite: 15.

25S—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Mr. FINCH and Assistants.

Survey 1 consists of running a line of levels for a water main or sewer, plotting profile, and computation of excavation. *Survey 2* consists of a topographic survey with plane table. Intersection, re-section, and traverse methods to be used, and map made. *Survey 3* consists of a topographic survey with transit and stadia; note-book and map. An optional course in photographic surveying may be offered in 1912. *Survey 4* consists of solar observations with transit and solar compass for the determination of the true meridian and magnetic declination. *Survey 5a*, City surveying, consists of the division of land into city blocks and subdivision into lots and the location of the street and lot lines; grade lines for streets and grades at street intersections; location and grade of sewers; including map, profile, and computation of excavation for street opening and sewer line. Relocation of lot lines and problems in surplus and deficiency, map showing property with record line and encroachments. Location of lines for buildings, bridge abutments, etc.

Pre-requisite: 15.

26S—Surveying between the Third and Fourth Years. Hydrographic Survey. Field and office work. 2 weeks. Mr. FINCH and Assistants.

Survey made in conjunction with Geodetic Survey (total time 5 weeks, see page 70, Dept. of Astronomy), which furnishes main triangulation net for topographic and hydrographic control. Hydrographic survey consists of auxiliary triangulation, topography on shore by stadia, soundings, observations on outlet by current meter for river discharge, adjustment of angles, computation of triangulation system, also of river discharge, map and report.

Pre-requisite: 25.

26aS—Limnology. Field and office work. 3 weeks. Mr. FINCH and Assistants.

This work covers the physics, chemistry, and biology of lakes and reservoirs. The location of Camp Columbia near Bantam and adjoining lakes and ponds offers a favorable opportunity for the study of this subject which is of great importance in water supply work. The course includes a study of currents, waves and seiches, thermal stratification; stagnation effects, microscopic examination and the control of algae growth in reservoirs, turbidity, etc.

Pre-requisite: Chemistry 78-79.

27S—Surveying between the Second and Third Years. Field work and office work. 5 weeks. 5 surveys. Mr. FINCH and Assistants.

Same as C. E. 25 except *Survey 5a* is omitted and *Survey 5b* is added. *Survey 5b* consists of the location of a mining claim 1,500 feet long by 300 feet wide in conflict with existing claims, and the determination of the areas in conflict. The claim is located upon an outcrop of assumed dip and strike, in such a manner as to keep the center line close to the outcrop. Reports and maps.

Pre-requisite: 15.

28S—Surveying between the Second and Third Years. Field work and office work. 3 weeks. Mr. FINCH and Assistants.

Railroad surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computation—Economic comparisons from construction and operating standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, calculations of earthworks, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 23, 27.

51-52—Theory of Railroad Surveying. 2 hours and 1 afternoon, first half-year, and 3 hours and 1 afternoon second half-year. Professor LOVELL and Mr. FINCH.

Simple, compound, and reversed curves—Transition curves—Switch work—Cross-section work—Earthwork computations—Cost of earthwork; cut and fill—Borrow—Waste and overhaul—Office work; Profile with mass curve showing proper distribution of excavation. Lectures and practical problems. Reference books: Searle's *Field Engineering* and Crandall's *Transition Curve and Earthwork.*

Pre-requisite: 15.

53-54—Elasticity and Resistance of the Materials of Engineering. 5 hours lectures and recitations first half. 6 hours first half-year of problem, design and laboratory work; 3 hours second half. Professors BURR and NORSWORTHY, Mr. MACGREGOR and Assistants.

Laws of elasticity in homogeneous materials—Coefficients of elasticity—Relations between stresses and strains—Common and exact theories of torsion and flexure—Elastic limits, working stresses, and ultimate resistances of wrought iron, cast iron, steel, alloys, timbers, building-stones, cement, concrete, and masonry—Reinforced concrete construction—Complete treatment of simple and continuous beams—The design and construction of iron, steel, and timber columns and beams, including the design and construction of plate girders—Shafts—Cables—Fatigue of materials—Specifications—Testing Laboratory—Discussion of properties of structural materials as shown by results of testing, by tension, compression, bending, and torsion—Report of tests. Reference and text-book: Burr's *Elasticity and Resistance of Materials.*

Pre-requisite: Mechanics 102.

57a—Sanitary Statistics and Reports. 20 lectures. Professor JACKSON.

Collection, preparation and interpretation of vital statistics, for the identification of the sanitary condition of particular States, cities, or communities as affected by water and milk supplies, sewerage systems, industrial and economic conditions. Reference book: Newsholme's *Vital Statistics.*

57b—Drainage of Marshes and Lowlands. A course of 10 lectures. Professor JACKSON.

Mosquitos, habits, breeding, methods of extermination. Malaria, yellow fever.

Pre-requisites for courses 57*a* and 57*b* are Chemistry 78 and 79, and Civil Engineering 59.

58—Masonry Structures. 3 hours and 1 afternoon with frequent conferences and continuous work in design. Cement and mortar testing in the cement-testing laboratory are required of all students. Professor NORSWORTHY.

Pressure and abutting power of earth—Design and construction of retaining walls—Stability of masonry structures in general—Stability of towers and chimneys under wind pressure—Theory and design of arches with vertical and inclined loads—Theory and design of reservoir walls, earth and high masonry dams—Theory and Design of masonry domes—Cement, concrete, and masonry. Reference books: Ketchum's *Walls, Bins and Grain Elevators;* Morrison and Brodie's *High Masonry Dams,* and Baker's *Masonry and Foundations.*

Pre-requisite: Mechanics 102, Mineralogy 5.

59—Sanitary Treatment of Water Supply and Sewage. 2 hours a week throughout the term and 2 afternoons in October in the Bacteriological Laboratory. Professor JACKSON.

Theory and construction of sand filters—Pollution of potable water and its purification by methods of sterilization and filtration—Mechanical filtration—Design of sand filters for water purification—Biology and Bacteriology of drinking water—Treatment and disposal of sewage and refuse of manufacturing—Sedimentation

by gravity and by chemical precipitation—Treatment by continuous and intermittent sand filtration—Septic tanks—Contact beds—Percolating or trickling filters—Continuous flow tanks—Intermittent application to soil with under-drainage—Disposal of sludge—Plants for sewage treatment. Text-books: *Public Water Supplies,* Turneaure and Russell; *Purification of Sewage,* Kinnicut, Winslow and Pratt.

Pre-requisite: Chemistry 82.

61—Analytical Theory of Trusses. 2 hours and 1 afternoon, with frequent conferences and problems in computations of stresses and preparation of stress sheets. Professor NORSWORTHY.

The truss element—Simple cantilever and non-continuous trusses with parallel chords—Fixed and moving loads—Through and deck spans—Positions of any system of concentrated moving loads for greatest chord and web stresses when chords are both parallel and non-parallel—Combination of moments and graphic methods—Skew and irregular trusses—Applications to bridge and roof trusses—Braced arches and arched ribs. Reference and text-book: Burr and Falk's *Metallic Bridges.*

Pre-requisite: Mechanics 102.

62—Graphic Statics. 2 hours and 1 afternoon. Professor NORSWORTHY.

For students in Civil Engineering—Equilibrium polygon, and polygonal frames for all systems of loads—Graphical representations of shears and moments for both non-continuous and continuous beams—Fixed and moving loads—Lines of influence—Applications to bridge and roof trusses. Reference and text-book: Burr and Falk's *Influence Lines.*

Pre-requisite: Mechanics 102.

64—Graphic Statics. 1 hour and 1 afternoon for mining engineers and metallurgist. Professor NORSWORTHY.

An abridged course, covering the subjects taken in Course 62.

Pre-requisite: Mechanics 102.

71S—Surveying between the Third and Fourth Years. Field work and office work. 4 weeks. Mr. FINCH and Assistants.

Railroad Surveying—Reconnaissance—Preliminary survey—Location—Cross-sectioning—Computations—Economic comparisons from construction and operation standpoints—A complete survey for the location of a line two to five miles long is made, with all the attendant computations requisite for placing the work under contract. Maps, plans, profiles, earthwork quantities, estimates and specifications. Daily conferences with instructor in charge of party.

Pre-requisite: 51-52 and 25.

75—Hydraulics. 3 hours, with conferences and problems. Mr. FINCH.

Hydrostatics—Laws of hydraulics—Measurement of head, pressure and flow—Gages—Manometers—Venturi meter—Current meter—Flow through orifices—Weirs, use, construction and discharge—Flow and discharge of pipes—Compound Pipes and branches—Flow in and discharge of open channels—Canal design—Stream gaging by current meter, floats, etc.—Graphical solution of hydraulic problems—Backwater—Elements of flow of compressible fluids. Text-book: Merriman's *Hydraulics.*

Pre-requisite: Mechanics 102, Math. 64-65.

76—Hydraulics. 2 hours. Mr. FINCH.

For students in Chemical and Mining Engineering—Course 75 abridged.

Pre-requisite: Mechanics 102, Math. 64-65.

77—Hydraulics. 2 hours. Mr. FINCH.

For students in Electrical Engineering—Similar to Course 75, but shorter. In addition it deals with the general considerations of rainfall, evaporation, percolation, run-off, net yield and storage; conduction of water from source to power-

house, hydraulic losses and effective head on wheel; estimation of power. Text-book: Merriman's *Hydraulics*. Reference book: Turneaure and Russell's *Public Water Supplies*.

Pre-requisite: Mechanics **102**, Math. **64-65**.

78—Hydraulics. 2 hours. Mr. FINCH.

For students in Metallurgical and Mechanical Engineering—Same as **76**.
Pre-requisite: Mechanics **102**, Math. **64-65**.

85—Foundations. 2 hours, with frequent conferences and work in design. Professor BURR.

Earth foundations—Foundations for buildings—Safe loads on masonry and foundation beds—Pile driving and pile foundations—Safe loads for piles—Protection and preservation of piles and timber—Sheet piling and coffer-dam methods—Pneumatic foundations and caisson work—Open dredging—Bridge piers of masonry and cylinders—Piers for deep foundations—Methods of working in quicksands—Tunneling. Reference books: Patton's *Foundations* and Baker's *Masonry and Foundations*.

Pre-requisite: **58**, Geology **18**.

87-88—The Design and Construction of Bridges, Roofs, and Buildings. 2 hours and 1 afternoon, with frequent conferences and continuous work in design. Professors BURR and NORSWORTHY.

Railway and highway bridges—Pin and riveted connections—Single and multiple system of bracing—The design of details for bridges, roofs, and buildings—Floors for railway and highway bridges—The design and operation of draw-bridges, including engines, locking, lifting, and turning machinery—Cantilever structures—Wind roads and stresses—Single and double-track viaducts or trestles in iron, steel, and timber—Lateral and transverse systems of bracing—The design and construction of elevated railroads—The complete designs of railway structures, with estimates of cost—The erection of iron, steel, and timber structures, including the cost of erection. First half-year only for sanitary engineers. Reference and text-books: Burr and Falk's *Influence Lines;* Burr and Falk's *Metallic Bridges*.

Pre-requisite: **53-54**, **61-62**.

89-90—Railroad Engineering. 3 hours and 2 afternoons for conferences and design work. Professor LOVELL and Mr. FINCH.

Location, construction and operation—Train resistance, sources and probable value—Curvature and grades, their relation to velocity and maximum train-load—Effect of momentum—Reduction of grades at starting points—Balance of grades for unequal traffic—Study of annual reports—Analysis of operating expenses—Cost of operating, including maintenance, per train mile—Itemized statements of costs and percentage to total cost—Cost of extra distance, curvature, rise and fall, or of additional trains—Effect of roadbed on cost of running trains—Justifiable expenditure in construction to save one mile of distance, one degree of curvature, one foot of rise and fall, or to reduce ruling grade .1% per daily train per year—Pusher grade for one or more assistant engines—Economical use of pusher grades—Cost of excessive or limiting curvature—Value of additional traffic—Principles to follow in locating new lines—General policy of improvements in old lines—Principles in design and construction of railroad yards and terminals—Computations and detail drawings of turnouts, slip switches and ladder tracks—Development and present practice in block signalling and interlocking, with problems in design and estimates of cost of installation—Classification and cost of earthwork—Graduation, cross section in excavation and embankment, and protection of slopes—Ordinary and extraordinary methods of drainage—Water supply, its quality, storage, and delivery—Design of standard maintenance of way plans, including ballast—Track and track accessories—Organization—Management. Reference books: Wellington's *Railway Location—Elements of Railroad Engineering,* Raymond—*American Railway Transportation,* Johnson—*Railway Signaling,* Latimer—Camp's *Notes on Track*—Dewsnap's *Railway Organization and Working*.

Pre-requisite: **71**.

94—The Design and Construction of Sewers, and River and Harbor Improvements. 2 hours lectures, recitations, problem and design work. Professors BURR and JACKSON.

Sewerage and surface drainage of cities and towns—Separate and combined systems of sewers—Capacities of mains and branches—Catch basins—Manholes—

Chimneys or ventilators—Flush tanks—Outfalls—Grades—Flow or discharge of sewers—Construction. River and Harbor Improvements—Jetty system of river improvements—Scouring action of currents—Erosion of river banks—Dams for improvement of river navigation—Breakwaters—Dykes—Groins—Mattress work—Docks—Harbor works—Iron piers—Estimates of cost. Text and reference books: *Sewer Design,* Ogden; *Sewer Construction,* Ogden.

Pre-requisite: 26, 59, 75.

96—Principles of Hygiene, Sanitary Science and Public Health. 3 hours. Professor JACKSON.

Health and disease; the germ theory of disease; dust and its dangers; infection and contagion; drinking water, ice, milk, vegetables, shell-fish, etc., as vehicles of disease; flies and other disease carriers; general problems of public health and sanitation. Reference books: *Principles of Sanitary Science and Public Health,* Sedgwick; *Sources and Modes of Infection,* Chapin; *Preventive Medicine and Hygiene,* Rosenau.

Pre-requisite: Civil Engineering **57***a* and **57***b*, Chemistry **78** and **79**, C. E. **59.**

97—Water Supply, Water Power and Irrigation. 3 hours lectures, recitations, problem and design work. Mr. FINCH.

Water Supply—General problem—Quantity required—Detection and prevention of waste—Metering—Methods of supply—Rainfall, run off and flood flows—Storage—River and lake intakes—Underground flow and wells—Gravity supplies—Storage reservoirs—Aqueducts and pipe lines—Equalizing reservoirs—Pumping—Elevated tanks and standpipes—Distributing system—Operation, construction and maintenance—*Water Power*—The hydrograph—Relation of load curve, pondage, etc.—Effect of flood flows on head—Flashboards—Construction—*Irrigation*—Extent—Duty of water—Elements of design—Reservoirs—Headworks—Canals and flumes—Application of water. Reference books: *Public Water Supplies,* Turneaure and Russell—*Water Power Engineering,* Mead—*Irrigation Engineering,* Wilson.

Pre-requisite: 26, 59, 75.

99-100—Graduation Thesis. A project or thesis on some civil engineering subject, approved by the head of the department, is required of every candidate for the degree of Civil Engineer.

Advanced Courses

The advanced courses in the department of Civil Engineering qualifying for the University degrees of Master of Arts and Doctor of Philosophy (those courses which fulfill the residence requirements) are the following:

153-154—Elasticity and Resistance of Materials. Half course.

257-258—Elastic and Masonry Arches. Open to those who have taken **57-58.** Conferences, reading and design work, as required. Half course.

275-276—Hydraulics (**75** with additional reading). Half course.

285-286—Foundations, including theory of earth pressure (**85** with additional reading). Half course.

287-288—Long Span Bridges. Open to those who have taken Civil Engineering **87-88.** Conferences, with reading and design work as required. Half course.

291-292—Railroad Location: advanced work in the Economics of Railroad Location, including a study of railroad operation with special reference to the application of the economic principles in the re-location of some existing railway or the location of a proposed road. Plans, Profiles and Estimates. Pre-requisite: Courses 89-90. Half course.

259-260—Sanitary Engineering. Pre-requisite: Courses 59, 94, 98. Full course.

277-278—Hydraulic Engineering, including the hydraulics of rivers and power plants and municipal water-works. Full course.

289-290—The Engineering of Structures, including long span bridges and deep foundations, with methods of building them, and advanced work in Elasticity and Resistance of materials. Full course.

293-294—Railroad Engineering: the design of the Permanent Way, including plans and specifications for roadbed, tunnels and culverts, track and track structures, yard and station layouts, block signals and interlocking. Pre-requisite: Courses 53-54, 58, 75, 85, 87-88, 89-90, and Mining 53. Full course.

DRAFTING

The drafting rooms and offices, situated on the fourth floor of the Engineering building, are equipped with a standard form of drafting table, and have a seating capacity for 175 students.

The collections of the department contain a complete set of models illustrating problems in projections and descriptive geometry, as well as the usual charts, blue prints, and models for use in the lecture and drafting rooms. A special feature of the collection is a full set of Olivier models illustrating the warped surfaces and problems in intersections and tangencies.

1, 2—Drafting. 1 hour and 14 hours drafting.

(*a*) Elements of mechanical drafting—Use of instruments; plane problems; free hand lettering; dimensioning; (*b*) Projections—Orthographic projection; intersections; developments; problems in descriptive geometry; isometric projection; cabinet projection; (*c*) Machine drafting—Conventional signs for materials of construction; sketching of machine details. Working drawings; tracings; blue printing; (*d*) Topography—Conventional signs; hill shading; mapping.

3, 4—Descriptive Geometry. 3 hours.

Problems on point, line, and plane; classification of surfaces; tangent planes to single curved surfaces and surfaces of revolutions; intersections; developments; warped surfaces.

5, 6—Drafting. 6 hours. Professors Mayer, Miller and Harrington.

(*a*) Graphics—Shades and shadows; perspective; (*b*) Stone cutting—Buttress; wing-wall; arches.

Pre-requisite: Drafting 1-2, 3-4.

7, 8—Drafting. 6 hours. Professors MAYER, MILLER and HARRINGTON.

(*a*) Structural drafting—Standard rolled sections; conventional riveting signs; standard connections; methods of framing and detailing structural work; beams; columns; plate girder; roof trusses; bridge details; (*b*) Machine drafting—Working drawings; tracing and blue prints of machine details; boiler and engine-room layouts, etc.

Pre-requisite: Drafting 1-2, 3-4.

ECONOMICS

2—3 hours. Professor SEAGER and Dr. HAIG.

Introduction to Economics. Lectures, reading and text-book discussion. In this course the fundamental principles of economics are studied with particular reference to their application to current economic and social problems in the United States, and with special regard to the needs of students in engineering. Third-year students in Electrical and fourth-year students in Mechanical Engineering.

ELECTRICAL ENGINEERING

2—Elements of the Dynamo. 2 hours. Professors ARENDT, MORECROFT and Mr. HEHRE. (1 quiz period for E.E. students.)

A general consideration of the principles and parts of Dynamo Electric Machinery. History, definition of dynamo and motor, reversibility of functions, magnetic field, magneto-motive-force, hysteresis, elementary dynamo, generation of e.m.f., collector rings and commutator. Parts of the dynamo; the magnetic circuit, materials and function. The armature core: materials, eddy currents, forms, construction. The armature winding. material, function, multiplication of electro-motive-force, types. The commutator: materials and construction. Brushes: function, materials and supports. Field frame: materials, forms, development of magnetic flux, windings, magnetic leakage. Armature reaction: cause of, back and cross ampere turns, brush shifting, sparking at brushes and remedies. Action of different types of dynamos, and typical forms. Text-books: Vol. I; Sheldon's *Dynamo-Electric Machinery;* Moncroft's *Continuous and Alternating Current Machinery.*

Pre-requisite: Physics 3-4 and 5.

4—Electric Distribution. 2 hours. Professor SLICHTER.

Principles and Methods of transmitting, distributing and controlling direct currents. Introductory, direct current series and parallel systems, feeders and mains, voltage regulation, networks, high tension d.c. systems.

Principles of alternating currents, self and mutual inductance, capacity, impedance, effective values of current and voltage, phase angle and power factor. Text-book: Crocker's *Electric Lighting,* Vol. II.

For E.M., C.E., Met.E., Chem.E. and San.E. students.

Pre-requisite: E.E. 2, Phys. 5.

5—Alternating Current Engineering. 105 abridged for C.E. students. 1 hour. Professor ARENDT.

52—Design of Direct-Current Machinery. 2 hours and 1 afternoon. Professor ARENDT.

Application of electrical and mechanical theory to the design and calculation of D. C. machinery with complete and original designs of generators or motors in accordance with specifications, requiring all calculations and working drawings. Reference books: Thompson's *Design of Dynamos,* Cramp's *Continuous Current Machine Design;* Arnold's *Gleichstrom-machinen,* Vols. 1 and 2.

Pre-requisite: E.E. 2 and 101. Parallel course: E.E. 173-174.

54—Design of Alternating-Current Machinery. 2 hours and 1 afternoon. Professor SLICHTER.

The application of alternating current theory and practical data to the calculation and design of alternators, transformers, induction motors and other alternating current apparatus. Reference books: Arnold's *Wechselstromtechnik;* Thompson's *Dynamo Electric Machinery,* Vol. II, and McAllister's *Alternating Current Motors.*

Pre-requisite: E. E. 52, 103 and 105 and Mechanics 108. Parallel course: Mechanics 110 and E. E. 175-176.

72—Direct-Current Laboratory. 1 hour and 1 afternoon. Messrs. HEHRE, MASON and Assistants.

Short Course for students in Mining, Metallurgical, Civil, Sanitary and Chemical Engineering. The experiments cover the following: Fall of Potential, Resistance determinations, Study of various types of D. C. generators, their connections and characteristics of operation. Working of generators in parallel. Study of various types of motors, their connections, characteristics of operation and determination of commercial efficiency by brake tests. The results of these experiments are handed in as reports which are returned promptly to the students, with comments and corrections. Text-book: Morecroft and Hehre: *Short Course in Electrical Testing.*

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2.

73—Direct-Current Laboratory Work. 1 afternoon. Mr. HEHRE.

Short course for students in Mechanical Engineering. Same as 72.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2 with parallel course E.E. 101.

75—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Messrs. HEHRE, MASON and Assistants.

Short course for Mining and Mechanical Engineering students. The experiments cover the following: Study of Elementary phenomena of alternating current circuits, with determination of inductance, capacity, impedance, true watts, apparent watts and power factor. Study of an Alternator, its operation, characteristic curves and wave form. Transformers: Their operation and commercial efficiency. Induction motors: Characteristics and efficiency by brake tests. Synchronous motors, their operation under various conditions and characteristic curves. Rotary converters, operation under various conditions of load and power factor (direct and inverted). Alternators in parallel, division of load and conditions for maximum economy. The student is required to prepare a report upon each experiment which is promptly corrected and returned to him for his instruction. Text-book: Morecroft and Hehre.—*Short Course in Electrical Testing.*

Pre-requisite: E. E. 72 or 73 and 4 or 104.

76—Alternating-Current Laboratory. 1 hour and 1 afternoon. Professor MORECROFT and Assistants.

Short course for Civil Engineers. Same as 75.

Pre-requisite: E.E. 4 or 104 and 72 or 73.

98—Thesis. Original investigation of and report on some problem of Electrical Engineering, approved of by the head of the department. Optional.

101—Generator and Motor Practice. 3 hours. Professor SLICHTER and Mr. HEHRE.

A course of lectures parallel to and descriptive of D. C. laboratory work. Short circuits and protective devices. Instruments: construction and use. Armature: e. m. f. current, resistance of, voltage drop in, windings and connections. Commutator: function, construction, heating, sparking, collecting brushes and holders. Magnetic circuit: calculation of flux and field windings. Heating of field and armature. Characteristics of the various types of generators and methods of

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regulation. Motors, theory of action and types. Methods of control and speed regulation. Losses and determination of efficiency by brake, stray power and pumping back methods. Text-books: Sheldon's *Dynamo-Electric Machinery.*

Pre-requisite: Phys. 5 and E. E. 2.

103—Electric Motors. 3 hours. Professor ARENDT.

(For E.E.) Electric motors, their action, control and application. Introductory. Classification of work requirements. Shunt Motors: Characteristics, predetermination of action, and efficiency, methods of speed control and regulation, rheostatic, field weakening, multiple voltage, double armature and teaser system. Series Motors: Connections, predetermination of characteristics and efficiency, control: rheostatic, field weakening, double armature and series parallel. Compound motor, characteristics and methods of control. Alternating current motors introductory. Commutator A. C. motors, series and repulsion types, characteristics and control. Synchronous Motors, characteristics and control. Induction Motors, single and polyphase, characteristics, methods of starting, speed control and regulation. Electric Drive, advantages of and application to machine tools, cranes, elevators, presses, pumps, fans, wood working and mill work. Text-book: *Electric Motors,* by Crocker and Arendt.

Pre-requisite: E.E. 104, 173 and 174. Parallel courses: E.E. 105 and 175-176.

103A—Electric Motors. 2 hours. Professor ARENDT.

Electric Motors, their action, control and application. 103 abridged for Mechanical Engineering Students.

Pre-requisite: E.E. 104 and 73. Parallel course: E.E. 105A.

104—Electric Distribution. 3 hours. Professor ARENDT.

Principles and methods of transmitting, distributing and controlling direct and alternating currents. Introductory, Physical properties of conductors, direct-current series and parallel systems of distribution, feeders and mains, voltage regulation, three-wire systems, high voltage direct-current systems, network systems.

Principles of alternating currents, study of wave shapes, inductance, capacity, phase angle, effective values of electromotive force and current, power factor, resonance, simple circuits, parallel circuits, line inductance and distributed capacity, calculation of single phase circuits. Text-book: Crocker's *Electric Lighting,* Vol. II. For third year E. E. and M. E. students.

Pre-requisite: Phys. 5 and E.E. 2 and 101.

105—Alternating-Current Engineering. 3 hours. Professor SLICHTER.

Electric power systems, including translating, controlling and transmitting equipments. Constant potential and constant current transformers, principles, efficiency, regulation and protection. Polyphase systems of generation, two phase and three phase, economy of generators, of transmission, and conversion from one system to another. Calculation of alternating current transmission lines, regulation of voltage and power factor of systems. Text-book: Steinmetz's *Electrical Engineering.*

Pre-requisite: E.E. 101 and 104.

105A—Alternating-Current Engineering. 2 hours. Professor SLICHTER.

105 abridged for Mechanical Engineering students.

Pre-requisite: E. E. 101 and 104.

106—Electric Plants. 2 hours. Professors SLICHTER and ARENDT and special lecturers.

Management of electric plants and industrial enterprises. Switch boards, materials, apparatus used upon, location and types. Line construction and protection, pole lines, cable and conduit systems, methods of charging for electric power, operating expenses, sources of income, organization and administration of corporations, reports, specifications, contracts, insurance regulations, patents and statistics.

Pre-requisite: E. E. 104 and 105.

108—Plant Inspection. 3 hours. Professors SLICHTER and ARENDT.

Pre-requisite: E. E. 104, 173-174. Parallel course: E. E. 105 and 106.

109-110—Telegraphy and Telephony. 1 hour. Professor ARENDT.

The principal methods and instruments employed in telegraphy, telephony and electric signalling. Telegraphy: Historical review, Morse systems, relays and sounders, earth circuits, station equipments, repeaters, differential and polarized relays, duplex systems, quadruplex systems, telegraphy from moving bodies, recording systems, submarine cables and telegraph circuits. Wireless telegraphy: Generation of electrical waves, simple transmitting and receiving apparatus. Telephony: Historical review, Bell's work, the magneto-telephone, the microphone and carbon transmitters, use of induction coils, call methods, series and parallel circuits, subscriber's equipment, line disturbances, common battery systems, subscriber's and exchange equipment, party lines, automatic systems, combined telegraphy and telephony. Reference-books: Maver's *American Telegraph Practice* and Miller's *American Telephone Practice.*

Pre-requisite: E. E. 104.

112—Electric Railway. 2 hours. Professor SLICHTER.

Special instruction in calculation, installation and operation of electric railway systems. Historical review and early development. Train resistances due to tracks and bearing surfaces, curves, grades, and air. Acceleration and breaking. Speed time curves. Motors for railway work. Controllers. Distribution systems, track construction, bonding and electrolysis. Trucks, wheels and car bodies. Conduit, storage battery and third rail systems. Electric locomotives and multiple unit control. Testing railway equipments. Financial considerations.

Pre-requisite: For E. E. students E. E. 104 and 173-174; for C. E. students E. E. 4 and 75.

173-174—Direct Current Laboratory. 6 hours (2 afternoons). Mr. HEHRE and Assistants.

1. Practice in the accurate use of voltmeters and ammeters for the measurement of electromotive force and current. Determination of resistance of the electrical circuits of electrical machinery by "drop," comparison and direct deflection methods. Use of Wheatstone bridge for determination of high resistance. 2. Generators: Preliminary study to bring out relations between speed, field strength and voltage. Operation of shunt, series and compound-wound generators with determination of characteristic action of each type. Distribution of potential around commutator and distorting effects due to armature reaction. 3. Motors: Function and operation of starting boxes, study of motors, existence and measurement of c.e.m.f., operation of shunt, series, compound and differentially wound motors, determination of speed-load curves of each type. Efficiency tests by brake and prediction methods. 4. Operation of shunt and compound-wound generators in parallel, methods of connecting, distribution of load, effects of individual differences, etc. 5. Heat runs, to determine load capacity and efficiency of generators and motors by "pumping-back" tests. 6. Tests on constant current arc generators, series boosters, balancer sets, three-wire machines, series-parallel control of railway motors, etc.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2. Parallel course: E.E. 101.

175-176—Alternating-Current Laboratory. 1 hour lecture and 6 hours laboratory practice (one whole day) first term, 1 hour lecture and 6 hours laboratory practice (2 afternoons) second term. Professor MORECROFT.

1. Alternating current circuits; determination of inductance, capacity, impedance, phase relations, true and apparent watts and power factor. 2. Alternators; operation at different power factors, magnetization curves, determination of losses and synchronous impedance, field compounding, etc. 3. Alternators in Parallel: division of load, cross currents and adjustment of excitation for maximum economy. 4. Synchronous Motors: Methods of synchronizing, efficiency, action under varying conditions of load and field current. 5. Rotary converters: Methods of starting, operation direct and inverted, compounding, determination of voltage ratios regulating pole rotary and determination of efficiency. 6. Transformers: operation, determination of losses, regulation, heating and efficiency. Use as induction regu-

lators and phase changers. 7. Wave Forms: determination of wave shapes and phase relations of electromotive-force and current in relative and non-relative circuits as well as in the primary and secondary circuits of transformers by instantaneous contact and oscillograph methods. 8. Resonance: by means of inductance and capacity in series, by inductance and leading current produced by synchronous motors, with application to transmission lines and rotary converter regulation. 9. Induction Motors: methods of starting, characteristic curves, determination of losses and efficiency by brake tests, application of circle diagram and use as frequency changer. 10. Induction Generator: operation and determination of the external characteristic. 11. Single-phase commutator motors, comparison of operation on a.c. and d.c. circuits; predetermination of characteristics by diagram. 12. Study of mercury arc rectifiers with curve analysis by ondograph and oscillograph. Text-book: Morecroft's *Laboratory Manual for Alternating Currents.*

Pre-requisite: E. E. 104 and 173-174. Parallel courses: E. E. 103 and 105; Mech. 109 and 110.

177—Instrument Laboratory. 1 hour and 2 afternoons. Mr. Mason.

1. Calibration of ammeters by comparison with laboratory standards. Kelvin balances, Siemens' dynamometers, and potentiometers. 2. Calibration of voltmeters. 3. Calibration, adjustment and determination of constants of A. C. and D. C. watt-hour meters, by various methods. 4. Determination of resistances: by Wheatstone bridge and potentiometer methods. 5. Measurements of Inductance and capacity. *a.* By comparison with standards using A. C. bridge. *b.* By absolute method, including determination of constants of ballistic galvanometer. 6. Magnetic measurements. Determination of coefficient of magnetic leakage of generator or motor. Determination of the permeability of samples of iron and steel. *a.* By Hopkinson's method. *b.* By Ewing double bridge method. *c.* A. C. voltmeter method. *d.* Direct reading voltmeter method. Determination of Hysteresis by Hopkinson's Double bridge. Voltmeter and Ewing tester methods. 7. Storage Battery Testing. Determination of normal rate of discharge, capacity and efficiency at normal rates, capacity at various rates. Constant current and constant potential methods of charging, weight efficiency and losses on standing. 8. Photometry. *a.* Proving gas meters and determination of candle power of gas against standard candles. *b.* Candle power incandescent lamps using standard candle. *c.* Distribution of light from an incandescent lamp, using secondary standard. *d.* Determination of mean spherical and mean hemispherical candle power of an incandescent lamp. *e.* Relations between voltage, candle power, efficiency and life of incandescent lamps. Arc lamp photometry. 9. Cable Testing. *a.* To determine insulation resistance; induction and capacity. *b.* To determine location of faults.

Pre-requisite: E.E. 173-174, E.E. 104 (Electric Distribution).

Graduate Courses

101, 104 and 173-174—Dynamo and Motor Practice, Electrical Distribution and D. C. Electrical Laboratory. 3 hours lecture and 6 hours laboratory. Full course.

Pre-requisite: Phys. 5, 43 and 44 and E.E. 2.

175-176—Alternating-Current Laboratory. With Mechanics 109 and 110. 5 hours first half-year, 4 hours second half-year and 2 afternoons. Full course.

Pre-requisite: E. E. 104, 173-174, and Mechanics 108.

103, 105, 106, 175-176—Electric Motors, Alternating Current Engineering and Electric Plants, and Electrical Laboratory. 7 hours, 2 afternoons first half-year; 3 hours, 2 afternoons second half-year. Double course.

Pre-requisite: E. E. 104, 173-174.

GEOLOGY

4—Petrography. 2 afternoons two months of the second half, third year. Professor BERKEY.

A short course in the microscopic study of rocks.

Pre-requisite: Mineralogy 6.

5-6—General Geology. 3 hours lectures, second year. Professors KEMP, GRABAU and BERKEY.

First half-year physical geology, with practical work in the rock collections under the lithological part of the subject; second half-year, stratigraphical and historical geology, involving laboratory work with index fossils and collections illustrating the geology of the United States. Text-books: Kemp's *Hand-book of Rocks;* Scott's *Introduction to Geology.*

Pre-requisite: Mineralogy 1-2.

15—Elementary Palæontology. Professor GRABAU.

An introduction to the study of fossils. 1 hour lecture and 2 hours laboratory.

16—Index Fossils. 1 hour lecture, 6 hours laboratory, second term. Professor GRABAU and Mr. KNIGHT.

A study of the invertebrate fossils characteristic of the various geologic horizons of North America.

Pre-requisite: Geology 5-6.

18—General Geology. Professor BERKEY.

A general discussion of dynamical, structural and historical geology, with practical work in the rock collections and assigned field work on Saturdays during the last six weeks. Special course during the second half-year for students in Civil Engineering only.

Pre-requisite: Mineralogy 5.

51—Principles of Geology. 2 lectures per week. Professors GRABAU and BERKEY.

Principles of the formation of sedimentary deposits, involving a discussion of marine and continental sedimentation, the criteria by which various sediments can be recognized, methods of preservation of organic remains, and the principles of geographic and geologic distribution of organisms. Principles of correlation. Text-book: Grabau's *Principles of Stratigraphy.*

Pre-requisite: Geology 5-6 or 18.

52—Principles of Geology. 2 lectures per week, second term. Professors GRABAU and BERKEY.

A discussion of secondary structural features; and of formation of folds, faults, etc. Vulcanism, metamorphism, secondary mineralization.

Pre-requisite: Geology 5-6 or 18.

101—Applied Petrography. 2 hours lectures and 1 afternoon laboratory work. Professor BERKEY.

Interpretation of rocks based on microscopic study. Rock origin, history, and present condition. Problems connected with ore deposits. Special course first half-year for students in Mining Engineering.

Pre-requisite: Geology 4.

102—Petrography of the Ores. Professor BERKEY.

This course is intended only for advanced students in petrography and economic geology. The chief object is to furnish a petrographic basis for the determination of the composition, structure and genesis of ores and ore deposits.

Pre-requisite: Geology 4, 101, 105 and 106.

105-106—Economic Geology. 3 hours lectures and one elective conference, third year. Professor KEMP.

First half-year, discussion of the general features and formation of ore bodies, followed by a description of the deposits of the ores of iron, copper, lead, zinc, silver, gold, and the lesser metals, with especial reference to North America; second half-year, a description of the distribution and occurrences of coal, petroleum, natural gas, asphalt, building-stone, water supply, salines, and minor minerals. Text-book: Kemp's *Ore Deposits of the United States and Canada,* and lecture notes privately printed.

Pre-requisite: Geology 5-6.

107-108—Invertebrate Palæontology. 2 hours lecture and 4 hours or more laboratory. Professor GRABAU and Mr. KNIGHT.

First part of the course deals with the principles of palæontology; methods of study of the ontogeny of hard parts of animals, and the laws of morphogenesis. This is followed by a consideration of the classes of invertebrates important from a palæontologist's point of view, emphasis being laid on the features which show genetic relationship. Special attention is given to groups whose evolution has been worked out. Text-book: Zittel-Eastman, *Text-book of Palæontology,* Vol. I.

Pre-requisite: Antecedent work in Geology.

110—Geological Examinations and Surveys. 2 hours, second half fourth year. Professor KEMP.

A discussion of the methods of systematically recording and interpreting geological phenomena, with illustrations drawn from experience in mining and other branches of engineering; and of the organization and scope of geological surveys on a larger scale. This is followed by a sketch of the history and results of state and national geological surveys in this and other countries; and of other sources of detailed information regarding local geology.

Pre-requisite: Geology 105-106.

112—Field Geology. All the officers of the Department.

A summer course of a week or ten days near New York for students in the course of Mining Engineering. Graduate students in the department may join the party. Instruction is given in the field in observing, recording, and interpreting geological phenomena and in the preparation of maps and sections. A written report is required.

Pre-requisite: Geology 5-6.

Geology 105-6 is desirable although not required.

201-202—Petrology. 2 hours lectures and 4 hours laboratory, fourth year. Professors KEMP and BERKEY.

A discussion of the origin, microscopic structure, and mineralogical composition of the crystalline rocks, and of metamorphism.

Pre-requisite: Geology 4.

205-206—Comparative Geology of North America. A comprehensive discussion of the geological formations and structure of the North American Continent. 3 hours lectures and 3 hours laboratory, with reading. Professors KEMP and GRABAU.

Pre-requisite: Geology 5-6 and 16.

LAW

Business Law. 2 hours. Professor GIFFORD.

A discussion of the elementary rules of law governing business transactions, including contracts, agency, commercial paper, sales, suretyship, bailments, torts, partnership, corporations. The rules of law are developed and illustrated by examples taken from the law reports, and dealing with situations such as engineers have in fact met and are apt to meet in the practice of their profession.

MATHEMATICS

1—Algebra. 3 hours.

3—Analytic Geometry. 3 hours.

64—Calculus. 5 hours.

For details in regard to the foregoing courses reference should be made to the Announcement of Columbia College.

65—Calculus. 5 hours. Professors MITCHELL, FITE, SICELOFF, Dr. REDDICK, Dr. GRAVES and Dr. FISCHER.

Continuation of 64. Further study of the differential calculus; the principles of the integral calculus; applications to geometry, physics and mechanics. First term of second year.

Pre-requisite: 3 (or 4), and 64 (or 67).

67—Calculus. Professors MACLAY and GROVE.

Equivalent of 64. First term.

68—Calculus. Professors MACLAY and GROVE.

Equivalent of 65. Second term.

MECHANICAL ENGINEERING

11-12—Steam Power Machinery. 3 hours, with 1 afternoon in the second half-year only. Professors LUCKE and PRESTON.

Functions, Forms and Principles of Operation of the Typical Steam power Plant Units, Auxiliaries and Connecting Elements—Methods of receiving, storing and firing coal, coal handling machinery, grates, stokers and furnaces for the combustion of coal; smokeless combustion and smoke ordinances; flow of gases through boilers, flues, dampers and the generation of necessary draft by chimneys, fans and steam jets. The construction and operation of boilers, boiler settings and foundations. Methods and apparatus for feeding water to boilers, necessary boiler attachments and trimmings. Flow of steam from boilers to engines and the grouping of engines and boilers, piping, valves, fittings and pipe covering. The heating of boiler feed water in feed water heaters and economizers. Purification of boiler feed water and effects of impure water on the boiler. Boiler strength tests and inspection laws. Boiler explosions. Steam pipe condensation and drainage. Steam traps, separators, steam superheating and superheaters. Condensing operation of steam engines by jet, surface, ejector and barometric condensers. Necessity for and types of circulating, hot-well and dry vacuum pumps and cooling towers. Typical steam engines and the variations in form and character of their important parts. Engine valves of simple and complete form, relation between construction of engine and valve gear to its economy. Special valve gears for high economy, for reserving and for power control. Regulation of engines and engine governors. Relation between engine construction, foundations, vibrations and balancing. Steam turbines. Typical steam plant arrangements for various special and standard conditions.

Second year mechanical and third year chemical engineering students.

Pre-requisite: Physics 3-4.

13-14—Steam Power Machinery. 3 hours. Professors LUCKE and PRESTON.

Short course adapted from M.E. 11-12. Second year Civil, Electrical and Sanitary; Third year Metallurgical and Mining Engineering.

Pre-requisite: Physics 3-4.

17-18—Engineering Thermodynamics. 2 hours. Professors LUCKE and THURSTON.

Laws of Heat Generation by Combustion, Heat Transfer and Transformation into Work—Relation between temperatures and quantities of heat. Units of heat. Effect of heat on solids, liquids, gases and vapors. Laws of heat transfer. Laws

of surface evaporation, ebullition and condensation. Properties of saturated and superheated vapors. Combustion of fuels, calorific power, quantities of air for combustion. Temperature of combustion. Boiler efficiency and conditions affecting. Principles of chimney draft. Laws of expansion and compression of gases. Work and heat diagrams to pressure volumes and temperature entropy co-ordinates. Air and wet vapor compression. Expansion of steam by hypothetic, adiabatic and saturation laws and application to steam engine efficiency. Missing water in steam engines. Influence of cylinder condensation, re-evaporation, steam jackets, initial superheat, compounding and reheating on steam engine efficiency. Relation of boiler and engine performance. Free expansion laws and application to injector and steam turbine nozzles. Heat transformation by perfect gases. Hot air, gas and oil engine efficiency. Mechanical refrigeration. Effects of evaporation of ammonia and carbonic acid and expansion of air. Heat balances and combined efficiency of complex systems.

Third year Mechanical, Electrical, Civil, and fourth year Chemical Engineering; Fourth year Sanitary, first term only; Fourth year Mining Engineering and Met.E. for first term.

Pre-requisite: M.E. 11-12 or 13-14.

19-20—Engine Design. 3 hours and 2 afternoons. Professor RAUTENSTRAUCH and Mr. MOSS.

Advanced Machine Design Based on the Thermal and Mechanical Problems Involved in the Design of a Steam Engine for Power, Economy and Regulation—Determination of ideal indicator card, probable M.E.P., piston speed, R.P.M., and displacement for required power, selection of single or multiple expansion construction from economy requirements, limits of clearance, cutoff, release, compression and admission for type of valve gear selected. Stresses due to steam and inertia in the principal parts. Forms and proportions of the parts determined by intensity, distribution and nature of the stresses, properties of the materials and conditions affecting maintenance. Determination of proportions of engine parts. Design of fly-wheels for limiting variation in velocity and analysis of resulting angular variation. Balancing the engine. Valve gears and governors, determination of the proportions of the valve for predetermined steam distribution, analysis of valve movements and moving gear. Graphic representation of the simultaneous events of valve opening, steam velocities and piston velocities. Analysis for the effect of the angularity of the rod. Equalizing the events of the valve. Analysis of the characteristics of the shifting eccentrics and the resultant variations in the valve events. Layout of the Corliss valve gear with single and double eccentric, and proportions of the mechanism. Steam engine governors, flyball and shaft governors, limits of movement, valve gear resistance. Proportions of the governor.

Fourth year Mechanical Engineering.

Pre-requisites: M.E. 17-18, 39, 40.

21 or 22—Gas Power Machinery. 4 hours and 1 afternoon. Professors LUCKE and THURSTON.

Theoretical and Practical Consideration Affecting the Generation of Power by Gas Engines, Including Oil Vaporization, Coal Gasification and the Design of the Machinery—Efficiency, M.E.P., displacement per minute per I.H.P. for reference diagrams. Limitations of external and internal heating. Methods of explosive and non-explosive internal heating. Properties of explosive gas mixtures, air necessary, calorific power per cu. ft. of mixture; temperature of combustion, heat suppression, efficiency of combustion, pressure and volume effects, limitations of proportions, temperature of ignition, rate of propagation, the explosive wave. Critical examination of modern gas engine forms and functions of parts; means for mixing and proportioning, pressure regulators, ignition; governors, effects on the engine and mechanism; starting equipment;exhaust piping and muffling; effects of back pressure in the engine; cooling; preignition, effect of cooling on economy. Large blast furnace practice, methods of gas cleaning; blast furnace gas, quality. Large engine construction, and forms of parts. Producer gas practice; standard producer for anthracite and bituminous coal, characteristics; gas, variation in quality, effects on the engine; methods of blasting producers, auxiliary steam supply and steam consumption; efficiency and rate of combustion in producer; scrubbers and tar extractors. Carburetors and vaporizers for liquid fuel; petroleum distillates, crude oil and denatured alcohol, vapor tension curves for liquid fuels. Characteristics of modern forms of gasoline and oil engines, gas power plant arrangements, producer engines, their efficiency, coal consumption and comparison with steam plants.

Complete analysis of the rating, efficiency, regulation, forces acting in and strength of parts of a modern gas engine. Probable indicator card, inertia of reciprocating parts, wrist pin and turning effort diagram. Dimensions of all parts.

Fourth year Mechanical Engineering.

Must parallel M.E. 19.

25-26—Steam Power. 2 hours and 1 afternoon first term and 2 hours and 2 afternoons second term. Professor PRESTON.

Relation Between the Cost of Power and Thermal Efficiency of the Plant. Commercial Value of Refinements—Determination of engine and boiler ratings and corresponding efficiencies and probable coal and water consumption for plant on given load curve. Essential relation between processes and dimensions of the steam plant. Steam plant refinements for raising efficiency of part or complete plant and relations between dimensions and effect. Use of unit costs of apparatus in estimating, examination of cost sheets to determine prime unit of cost. Cost of power. Fixed and operating charges, ratio of each individual item to total and effect of labor and fuel rates, load factor and refinements on the fractional part. Value of refinements of design on basis of capitalized annual saving by comparing the cost of waste and the cost of its elimination, including all charges. Specifications and contracts; standard and special methods and forms for defining purchaser's requirements and builder's proposals, contracts, methods of power plant erection. Designing and erecting office organization and field systems.

The work consists in laying out a simple power plant for assigned units in the drafting room or the detailing of existing general plant drawings, preparation of the bill of materials, estimating the first cost, fixed charges, probable coal, water, labor and supply cost for an assumed load curve and total power cost. The plants so designed or detailed are exchanged by students and redesigned for an increase of 100 per cent. peak and 50 per cent. mean daily load and for the maximum power cost reduction by the use of plant refinements and auxiliaries when it can be shown that additions and alterations will pay. Specifications are written for the alteration and proposals submitted.

Fourth year Mechanical Engineering.

Pre-requisite: M.E. 17-18

31-32—Standard Tests and Research Methods. 1 hour and 1 afternoon. Professor PARR and Mr. EDDISON.

Laboratory methods for the determination of experimental data. Derivation of physical laws from experimental results—Comparison of actual performance of machines with computed prediction and evaluation of unknown elements. Methods of approach for the solution of practical problems by experiment and computation. The work is illustrated by problems on the flow of liquids, gases and vapors, combustion, transfer of heat, steam generation and changes of state, transformation of energy, power generation and transmission, energy losses, thermal, hydraulic and mechanical. For each problem a preliminary report is submitted before the test, involving the analysis of the problem, the attempted prediction and the required test log, based on class-room explanations; this is incorporated with the tests results and an interpretation of differences between these and the prediction, including judgment of errors, to constitute the final report. The apparatus for this course includes: Pressure gauges, manometers, thermometers, pyrometers, indicators, tachometers, planimeters, barometers, weirs, channels, nozzles and orifices for water, steam and air, Pitot and Venturi tubes, steam, gas and water piping and meters, dynamometers, power scales, viscosimeters, flue gas apparatus, steam traps, hydraulic ram, steam injectors, air pump, hot air engine, duplex steam pumps, Pelton wheel, centrfugal pump, simple steam engine.

Third year Mechanical Engineering.

Pre-requisites: M.E. 11-12. Parallel: M.E. 17-18.

33—Standard Tests and Research Methods (Continuation of Course 31-32). 2 hours and 1 afternoon. Professor PARR and Mr. EDDISON.

The work of this course is the same in nature as 31-32, but the problems involve more difficult computations and more skilful manipulation of the apparatus. These problems are principally concerned with energy transformation, necessary and accidental losses and the determination of the conditions affecting performance of compound and triple expansion steam engines and pumps, operating condensing and non-condensing, with and without receivers, with and without reheaters. Hydraulic motors, one, two and three stage air compressors, with and without intercoolers, feed water heaters, fans, steam boilers, ammonia refrigerating machines, steam superheaters and condensers. Attention is also given to the commercial tests standardized by the Engineering Societies.

Fourth year Mechanical Engineering.

Pre-requisites: M.E. 31-32; M.E. 17-18.

35-36—Kinematics of Machinery. 1 afternoon. Professor THOMAS.

Determination of Paths of Motion, Velocity, Acceleration and Kinetic Forces of the Moving Parts of Machines with the Resulting Reaction Forces of the Frame—Relative motions of machine parts and the determination of the rates of motion. Determination of space, velocity and acceleration diagrams with application to the steam engine, shaper and other standard mechanisms. Construction and use of diagrams for the determination of inertia forces and their distribution in each element of a machine. The layout of motions to specifications. Design of cams with special reference to the rate of change of velocity of the moving parts and the resultant inertia forces, resistances to motion and the continuous contact of cam and follower. Analysis of link work, relative motions, inversions, adaptability to the accomplishment of specific kinds and limits of motion. Eccentrics and links for the transformation of kinds of motion; ratchet motion; running ratchets. Clutch and coupling mechanisms, connecting shafts in parallel and at an angle. Modification to permit of non-alignment. Toothed gearings. Justification of the cycloidal and involute curves in their application to gear teeth. The layout of tooth forms and the determination of the velocity ratios. Layout of bevel gear tooth forms by Tredgold's method. Approximate methods and practical rules for the layout of gear teeth. Determination of paths of contact, obliquity of motion, length of teeth, interferences in involute gearing. Determination of the necessary conditions for interchangeability in sets of cycloidal and involute gears and comparison of the system. Friction gears. Kinematics of belt drive. Open and crossed belts. Layout of sprocket wheels and chain drives, speed changing devices using wrapping connections.

Second year Mechanical and third year Electrical Engineering.

Pre-requisites are Math. 3-4 (M.E. 35 must parallel M.E. 59, M.E. 59 Pre-requisite for M.E. 36, for M.E. students).

37—Machine Design. 1 hour, 2 afternoons, first half-year. Mr. Moss.

Adapted from M.E. 39-40.

Fourth year Chemical Engineers.

Pre-requisite: M.E. 59.

39-40—Machine Design. 3 hours, 1 afternoon, first half-year, 3 afternoons, second half-year. Professor RAUTENSTRAUCH and Mr. Moss.

Analysis of stress in machine parts of standard form under varying conditions of service and the proportions of the machine elements to safely resist the resulting stresses—Application of the principles of Kinematics, Resistance of Materials, Design of Machine Elements, Shop and Foundry Methods to the design and analysis of complete machines. Examination of machines to determine the nature and distribution of the forces acting on and the resulting stresses and strains in each element due to kinetic and structural conditions. Selection of working stresses for machine parts subject to steady, repeated and reversed stresses. Selection of materials for machine parts based on their adaptability to the service and to the shop processes by which the part must be made. Determination of the proportions of machine parts subjected to tension, compression, and shear; bending and torsion; combined bending and tension, bending and torsion, torsion and compression, buckling action, and stresses due to eccentric loading and complex supports. Illustrated in the design of crank shafts, machine frames, housings and connecting rods. Gear wheels, pulleys, flywheels, springs, riveted joints, thin and thick cylinders, braces and stays, flat plate members, pressure joints, screws, belting, rope and chain drives for power transmission. Bearing surfaces, flat, cylindrical, pivot, ball, roller, thrust. Application of theory of elasticity to the more complicated elements. Grouping of machine elements into machines for functional operation, erection, adjustment, maintenance and repair and modifications demanded by facilities for manufacture. Design of machines to specification, with particular refrence to modern requirements.

Third year Mechanical Engineers.

Pre-requisites: M. E. 35-36. Must parallel C. E. 53.

41—Machine Design. 1 hour and 1 afternoon. Professor THOMAS.

A short course adapted from M. E. 39-40.

Fourth year Civil and third year Electrical Engineering.

Pre-requisites: C.E. 53 and M.E. 78 for C.E. M.E. 35-36 for E.E. Must parallel C.E. 53 for E.E.

45 or 46—Hydraulic Turbines. 3 hours. Mr. HERRICK.

Description of operating conditions of water turbines—Principles of design and economy of operation of turbine wheels and water power plants—Action of water on curved vanes, forces developed and effect of impact, work done; centrifugal action. Theory of the turbine. Vane form and arrangement; total work done for axial, radial and mixed flow wheels; dependence of velocity of flow on speed of rotation; losses of energy due to friction in guide passages, wheel buckets and sluice, chock, leakage, residual velocity. Design of reaction turbines; relation between pressure and velocity of flow; methods of determining passage areas; radii of wheels, width and depth of buckets, number and thickness of vanes. Application of the theory of axial flow, parallel flow and mixed flow turbines. Tangential impulse turbines; essential principles and theory, advantages, ventilation of bucket, velocity of flow, available energy, efficiency. Descriptions of and experiments with turbines of various types. Existing water power plants. Modern governors for turbines; ideal action of direct acting governor and disturbing influences; essential principle of indirect acting governor; factors affecting regulation. Selection and arrangement of water turbines and auxiliaries for different local conditions. Efficiency of turbines and plants.

Fourth year Mechanical Engineering (M.E. 45 and fourth year Civil Engineering (M.E. 46). Pre-requisites: For Mechanical Engineering: M.E. 36, M.E. 60, C.E. 78; for Civil Engineers: M.E. 78, C.E. 75, M.E. 63.

50 or 53—Steam Turbines. 3 hours. Professor PRESTON.

Fundamental Analysis of the Action of Steam Jets and Vanes and Its Application to the Design and Performance of Steam Turbines—Ratio of impulse to reactive force jets, effect of variation of curvature of the buckets, open and closed passages. Flow of steam through nozzles and turbine passages, volume, pressure, temperature, quality, weight, velocity and kinetic energy relations. Centrifugal effect of steam moving in a curved path. Study of the use of steam in varying types of turbines. Graded pressure turbines, graded velocity turbines, mixed impulse and reaction turbines. Practical turbines belonging to these types, and study of their detailed construction. Efficiency of different types studied by analysis of energy transformation throughout the path of steam and how efficiency is varied by design of blades, passages, nozzles, number of stages, speed, clearance, leakage and mode of regulation. Construction of turbine vanes. Disc and vane friction and critical speed. Governing steam turbines, throttling method, variable admission to one or more stages and periodic admission. Steam consumption of turbines.

Fourth year Mechanical (50) and Electrical Engineers (53)

Pre-requisites: M.E. 17-18, M.E. 31-32; for Electrical Engineers M.E. 17-18, M.E. 76

52—Organization and Management. 3 hours. Professor RAUTENSTRAUCH or Mr. MOSS.

Manufacturing Organizations and Methods of Cost Accounting—Effect of methods of manufacture and capacity on systems of management of mills and factories. Analysis of the elements of factory accounting and determination of the factors entering into the cost of production. Methods for keeping record of the cost of labor and materials in the production of specific articles. The determination of establishment charges. Interpretation of costs and use of comparative values. Determination of the depreciation of buildings, machinery, patterns, drawings and other assets. Organization and functions of the departments of the business. Purchase of raw material and sale of product. Utilization of scrap and waste. Methods of labor compensation. Critical analysis of the methods of accounting in representative factories. Factors affecting the cost of production. Layout of complete system of organization, forms and methods of accounting.

Fourth year Mechanical Engineering.

Pre-requisites: M.E. 94S, M.E. 54.

54—Shop Methods, Problems and Processes. 2 hours. Mr. HALSEY.

Methods of attack and solution of the problems of the shop. The two systems of production—making and manufacturing—contrasted, and their essential differences pointed out. Origin of the various machine tools and characteristic of the work of the pioneers. American and British machine tools and methods contrasted. Precision workmanship and its relationship to commercial workmanship. Accuracy of form, size and position. Methods of originating flat surfaces, squares, angles and index plates. Measurements. Fallacy of the metric system. Line and end measures; their relative accuracy and respective influences on shop organiza-

tion. The vernier, micrometer, multiplying lever and microscope. Measuring machines, gauges, limit gauges. Fits and limits. Turning and boring. Turret lathes, plain and automatic, and their equipment. Special tools and equipment. Boring bars. Floor plate work. Drilling. Methods of accurately spacing holes. Milling. Gear centering. Grinding. Balancing machine parts.

Third year Mechanical Engineers.

Pre-requisites: M.E. 94S and Shop Work 11.

56—Hydraulic Turbine Installations. 1 hour. Mr. Herrick.

Selection and Arrangement of Water Wheels, Governors and Auxiliary Appliances for Different Local Conditions, Efficiency of Wheels and Plants—Characteristic of water flow through turbine guides, nozzles and buckets, conditions warranting wheel classification, efficiency of wheels as a function of type, head, speed and part gate operation, effects of different forms of gate on efficiency, relative value of standard patterns and special designs to suit local conditions, limits of standard dynamo speeds on wheel speeds. Water wheel governors regulation. Available head at wheels and division of total loss throughout water conductor system, relation between available water supply, possible output and perfection of development work; draft tubes, stop valves, gates, vacuum and pressure relief stand pipes, relief valves and bye-passes, water racks, anchor and frazil ice. Analysis of typical installations. Water power costs.

Fourth year Electrical Engineering.

Pre-requisites: C. E. 77. Parallel course: M. E. 60.

59—Empiric Design. 2 hours and 1 afternoon. Professor Thomas.

Proportioning of Machine Parts by Empiric Methods and the Production of Shop Drawings and Sketches—Modern practice in making, recording and filing shop drawings of machine details and assemblies, bills of material and listing of standard and special parts. Use of standard conventions and interpretation of shop notes on drawings. Shop sketches and dimensions. Forms of machine parts as indicated by the nature of the resistances to be overcome and the characteristics of the material. Plain, box, and ribbed cast sections, shrinkage stresses and the probability of local weaknesses. Proportions of parts by modern empirical formulas derived from practical considerations. Limiting conditions in the use of empirical formulas. Modern practice in the proportioning of machine elements. Proportions of parts adopted by the Master Car Builders' Association, Master Steam Boiler Makers' Association, United States Government, numerous manufacturing concerns and data appearing in the transactions of the various engineering societies and engineering publications. Design of simple castings from assigned data, dies for forming simple parts in a bull-dozer and the frames and parts of simple machines having given the detailed drawing of the other parts necessary to the determination of the principal dimensions.

Second year Mechanical Engineering and third year Chemical Engineering.

Pre-requisites: Drafting 1 or 2.

60—Hydraulic Laboratory. 1 hour and 1 afternoon for one-half term. Mr. Herrick.

Practical Work on the Flowing of Water for the Determination of Rational Coefficients with Ordinary and Extraordinary Conditions—Flow through simple holes in plate and short tubes under low heads. Flow through convergent nozzles and needle orifice. Flow through straight pipe, elbows and joints, distribution across the cross section near bends with velocity. Flow over weirs. Variation of rectangular, trapezoidal and triangular, sharp versus dull edge, approach contractions, one side, both sides and bottom. Hook gauge measurements. Measurement of quantity flowing by Venturi tube and Pitot tube. Variation of error with type, pressure drop, and size. Loss of heads by sudden enlargement in cross section in pipes running full. Inertia and water shock. Water wheels. Variation of efficiency with speed and head, analysis of losses in nozzles, bucket and friction. Efficiency of the Hydraulic Ram Test for reliability on commercial water meters.

Fourth year Electrical Engineering and third year Mechanical Engineering, Met.E.

Parallel course: For Mechanical Engineering students, C.E. 78 for Met.E. Parallel C.E. 76.

Pre-requisite for Electrical Engineering students: C. E. 77.

63—Hydraulic Laboratory. 1 afternoon. Mr. Herrick.

A course based on M.E. 60. Fourth year Civil Engineering.

Parallel: Hydraulics, C. E. 75.

64—Air Machinery. 2 hours. Mr. LONGACRE.

Structures, Adaptability and Economy of Fans, Air, Gas and Vapor Compressors, Blowing Engines, Jet Blast Apparatus and Important Applications—Convection movement of air; flow of air through orifices, ducts, pipes. Hygrometric conditions of air with temperature and pressure and condensation of moisture in compressed air. Air compressors, types and construction; work of compression, M.E.P. for single and multi stage, cylinder ratios, effects of intercooling. Volumetric efficiency of compressors, real and apparent. Discharge pipe pressure pulsations, air receivers, intercooling receivers. Air end valves, poppet, slide, Corliss and ring valves, suction and delivery, differences in type and diameter and lift. Steam end valve gears and cylinder arrangement. Constant and variable speed compressor valve gear characteristics, pressure and speed controllers and governors. Analysis of complete compressor economy tests. Dry vacuum air pumps. Blowing engines, special forms and sizes of air end valves introduced by cylinders of large diameters for low pressure air. Ammonia and carbonic acid compressors; peculiarities and methods of handling liquid in the vapor; forms and characteristics. Multi-stage centrifugal fans and service. Analysis of efficiency tests for fans and blowers. Positive blowers. Steam jet blowers and exhausters, thermal efficiency. Application of principles to ventilation and heating, blast furnace practice, compressed air and compressed gas power transmission systems, air lift pumps and air brakes.

Third year Mechanical Engineering.

Pre-requisite: M. E. 17.

66—Elevators and Conveyors. 1 hour. Mr. MOSS.

Mechanical Handling of Solid Materials by Standard Elevating and Conveying Machinery, Characteristics, Speed, Tonnage and H.P. per Ton, Computations and Adaptability to Special Service—Hand handling of materials, limits, cost and conditions warranting use of machinery. Continuous conveyors, screw, bucket, scrapers, pusher, belt and pneumatic types. Intermittent conveyors; telephers, rope and cable ways, cable cars. Loaders, unloaders, storage facilities. Skips, grab buckets, tips and tipples. Short and long hoists, friction drum hoists and direct connected. Pneumatic and hydraulic elevators for freight. Fixed and travelling cranes. Passenger elevators, rope and plunger types. Safety devices. Automatic weighers of materials; coal and ore storage systems. Excavating machine and dredges. Coal and ore-handling machinery. Railroad terminal and steamship loaders and unloaders. Coke oven chargers and dischargers. Grain handling. Special adaptation to material, such as sand, plaster, glass, cement, broken rock, coal, coke, packages, barrels, corrosive, erosive, sticky, packing, and hot materials.

Third year Mechanical Engineering.

Pre-requisite: M. E. 39.

70—Pumping Machinery. 2 hours. Mr. NICKEL.

Reciprocating Pumps. Early and modern types. Efficiencies. Suction Lift. Air chambers. Capacity. Speeds. Power. Arrangement of pumps.

Pump End. Types. Valve service. Materials used for various liquids. Water works surface condenser. Steam End. Single pumps. Duplex pumps. Steam valve compound pumps. Triple expansion pumps. Plunger load. Duty. High Duty Pumps. Crank and flywheel. Direct acting. Centrifugal Pumps. Development of the fundamental equations. Volute pumps. Turbine pumps. Characteristics. Pistonless pumps. Pulsometers. Jet pumps. Hydraulic ram. Steam jet pumps.

Third year Mechanical Engineers.

Pre-requisites: M.E. 17. Parallel C.E. 78.

72—Gas Power Machinery. 2 hours and 1 afternoon. Professor THURSTON.

Short course adapted from M.E. 22.

Fourth year Electrical and Metallurgical Engineering.

Pre-requisite: M. E. 17-18.

74—Gas Power Machinery. 2 hours. Professor THURSTON.

Same as 72 except for the laboratory time.

Fourth year Mining Engineering.

Pre-requisite: M. E. 17-18.

75-76—Standard Tests. 1 hour and 1 afternoon. Professor PARR, Mr. HERRICK and Mr. RIEDEL.

Short course adapted from M. E. 31, 32, 33.

Fourth year Chemical Engineers.

Pre-requisites: M.E. 13-14. Parallel M.E. 17-18.

77—Standard Tests. 1 hour and 1 afternoon. Professor PARR, Mr. HERRICK, Mr. RIEDEL and Mr. EDDISON.

Short course adapted from M. E. 31, 32, 33.

Third year Civil Engineers, fourth year Chemical, and fourth year Electrical Engineers

Pre-requisites for Civil and Chemical Engineers: M.E. 13-14. Parallel M.E. 17; for Electrical Engineer, M.E. 17-18.

78—Kinematics. 3 hours. Professor THOMAS.

Short course adapted from M.E. 36.

Third year Civil Engineers, Sanitary Engineers. Pre-requisite: Math. 3-4.

80—Experimental Mechanical Laboratory. 1 hour and 1 afternoon. Professor PARR and Mr. EDDISON.

Laboratory methods for the determination of experimental data and instruction in the operation of standard machinery. Standardization of pressure gauges, vacuum gauges, draft gauges, thermometers, pyrometers and steam engine indicators. Methods of measuring brake and indicated horsepower illustrated by the determination of mechanical efficiency of a steam engine. Correct methods for starting, stopping and operating steam engines, steam pumps, air compressors, fans and internal combustion engines. Valve setting on steam engines and direct acting pumps. Variation of steam consumption with load in a simple steam engine. Variation of horsepower to compress one thousand cubic feet of free air per minute with discharge air pressure. Variation of steam consumption of a direct acting pump with pumping head. Variation of gas engine and oil engine economy with load. Measurement of water flow by means of weirs, venturi meters, pitot tubes, orifices, recording water meters of various type and weighing tanks, and the determination of the limits of usefulness and accuracy of each method.

Third year Mining Engineering.

Pre-requisite: M. E. 13. Parallel course: M. E. 14.

82—Heating and Ventilation. Mr. OHMES. 2 hours.

Principles of Heat Generation Transfer and Air Movement Applied to Warming and Ventilation of Buildings—Quantities of air needed for proper ventilation, amount of heat necessary to maintain temperatures against conduction, radiation and air change losses. Heating surface and coefficients of heat transfer, grate surface, pipe and duct sizes for high and low pressure steam heating, direct and indirect, hot water and hot air systems. Air tempering, cleaning, drying, humidifying. Pipe and duct layouts. Fan computations. Exhaust steam systems, vacuum circulation. Reducing valves, air valves, water expansion tanks, thermostats, thermostatic regulation systems and important details. Efficiencies of various systems and analysis of existing installations.

Fourth year Sanitary Engineers. Pre-requisite: M.E. 17.

94S—Shop and Factory Summer Work. Professor THOMAS.

Practical Work and Directed Study in the Shops and Drafting Rooms of Representative Manufacturing Establishments with Report—Each student is provided with a printed copy of the things to be studied and reported on in detail, of which the following is a general summary:

Machine Shop. Functional operation, characteristics and powering of machine tools, capacities, layout of shop, size of shafting, belting and motors for independent and group drive. Range of cutting speeds, feeds, depth of cut. Shape and size of tools used. Report on specific observations on time of setting work, time of forming and finishing, number of pieces turned out per hour. Facilities for handling work at the machine. Facilities for producing pieces in quantity. Hand processes for finishing and tools used.

Pattern Shop. Materials of which patterns are made and methods of treating. Machine tools used in the pattern shop arrangement, capacities, adaptability, handing and storing of material and finished product.

Foundry and Forge, Description of hand and machine tools and appliances used in the foundry and forge. Compositing and treatment of foundry sands. Methods of molding. Time involved. Methods of powering, venting and chilling, cooling and finishing, handling the cupola. Composition of the charges and mixtures, temperatures, pressures, time required to charge, to melt, to pour, cool and clean. Appliances in the forge shop. Operation of power hammers, bull-dozers, shears, heating and annealing furnaces and hand processes of forging. Time involved in production.

Drafting Room. Standards and conventions used. Filing and marking of drawings and recording of patterns. Bills of material—parts to be made—standard parts in stock.

General Management and Organization. Methods of recording time of workmen and their time distribution over on different jobs. Paying of men, methods, rates, forms and records used. Drawing of materials used from storeroom and charging to orders.

Report due on first day of registration.

Pre-requisite course is second year shop work.

96S—Steam Power Plant, Summer Work. Professor Preston.

Report based on not less than six weeks' practical work in an Operating Power Plant, including the Output, Load Conditions, Labor and Material for Operation and Maintenance, Operating Cost per Unit and the Essential Dimensional Relations between the Various Units and Auxiliaries Producing this Result—This work is done entirely by the student in the field, his only assistance being the blank report form which is put in his hands after a brief lecture on leaving the University for the vacation.

Report due on first day of registration.

Third year Mechanical Engineering. Pre-requisite courses: **M. E. 17-18, 31-32.**

97—Mechanical Apparatus for Chemical Factories. 5 hours for 10 weeks in First Term. Professor Thomas.

Characteristics of the principal types of machinery and mechanical apparatus used by the manufacturers of chemical products, including the fundamental principles upon which their design is based, the method of operation, the selection and installation to meet given conditions of service, size and capacity of each unit, and economical arrangement of the plant. Pumping machinery; direct acting steam, simple, compound and triple expansion, belt and motor driven piston and plunger pumps. Centrifugal and turbine pumps; single and multi-stage, screw and rotary pumps. Jet apparatus; injectors, ejectors, steam and water jet blowers. Hydraulic presses; accumulators, heavy hydraulic apparatus. Air machinery: fans, blowers, positive blowers, turbo-compressors, piston compressors for single and multi-stage compression, intercoolers, regulating devices and unloaders. Hydraulic compressors. Blowing engines. Rotary and plunger types of vacuum pumps, air lift pumps. Refrigerating machinery; compression and absorption systems using ammonia. Dense air and carbonic acid machines. Ice making by can and plate systems. Compressors, condensers, stills, brine coolers and other units in refrigerating plants. Methods employed in the transportation of solid materials; elevating and conveying machinery, continuous and intermittent conveyors, loaders, unloaders, adaptability of system to material to be handled; hydraulic and pneumatic systems of transportation. Crushing and grinding machinery; methods employed for dry and wet processes, the handling of hard and soft materials; jaw, gyratory and roll crushers; roll, tube and ball mills for fine grinding, burr-stone mills. Separating and screening machinery; construction and operation of the types used in wet and dry processes; centrifugal and shaking screens, bolting reels. Mixing machinery for dry, plastic and wet material, mixing tanks, beating engines. Drying machinery; classification of apparatus for obtaining different degrees of dryness; construction and operation of suction apparatus, press rolls, steam driers for paper, kilns for cement, wood, pottery, by means of air currents. Humidifiers. Washing and boiling machinery; washing engines, digesters, kiers. Recording apparatus. Regulating apparatus for pressures and temperatures. Measuring apparatus for water, gas and steam, weighing machinery for solid materials. Pipe, pipe fittings, valves, conduits and ducts.

Precedes and forms sequence with Chemistry 197. Fourth year students in Chemical Engineering. Pre-requisites: M.E. **11** and **12.**

Courses which may be Credited to the Degree of A.M. for Graduate Work Under the Faculty of Pure Science

Open only to students of Pure Science who have satisfied the pre-requisites.

117—**Engineering Thermodynamics.** 2 hours. Similar to M.E. 17, and subject to the same pre-requisites to entrance. One-half course. Professor LUCKE.

118—**Engineering Thermodynamics.** 2 hours. Similar to M.E. 18, and subject to the same pre-requisites to entrance. One-half course. Professor LUCKE.

119—**Engine Design.** 3 hours and 2 afternoons. Similar to M.E. 19, and subject to the same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH.

120—**Engine Design.** 3 hours and 2 afternoons. Similar to M.E. 20, and subject to the same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH.

121—**Gas-Power Machinery.** 4 hours and 1 afternoon. Similar to M.E. 21, and subject to the same pre-requisites to entrance. Double course. Professor LUCKE.

125—**Steam Power.** 2 hours and 1 afternoon. Similar to M.E. 25, and subject to the same pre-requisites to entrance. Double course. Professor PRESTON.

126—**Steam Power.** 2 hours and 2 afternoons. Similar to M.E. 26, and subject to same pre-requisites to entrance. Double course. Professor PRESTON.

131—**Mechanical Laboratory.** 1 hour and 1 afternoon. Similar to M.E. 31, and subject to same pre-requisites to entrance. One-half course. Professor PARR.

132—**Mechanical Laboratory.** 1 hour and 1 afternoon. Similar to M.E. 32, and subject to same pre-requisites to entrance. One-half course. Professor PARR.

133—**Mechanical Laboratory.** 2 hours and 1 afternoon. Similar to M.E. 33, and subject to same pre-requisites to entrance. Full course. Professor PARR.

145—**Water-Power Machinery.** 3 hours. Similar to M.E. 45, and subject to same pre-requisites to entrance. Full course. Mr. HERRICK.

160—**Hydraulic Laboratory.** 1 afternoon. Similar to M.E. 60, and subject to same pre-requisites to entrance. One-half course. Mr. HERRICK.

139—Machine Design. 3 hours and 1 afternoon. Similar to M.E. 39, and subject to same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH and Mr. Moss.

140—Machine Design. 3 afternoons. Similar to M.E. 40, and subject to same pre-requisites to entrance. Double course. Professor RAUTENSTRAUCH and Mr. Moss.

152—Organization and Management. 3 hours. Similar to M.E. 52, and subject to same pre-requisites to entrance. One-half course. Professor RAUTENSTRAUCH.

164—Air Machinery. 2 hours. Similar to M.E. 64, and subject to same pre-requisites to entrance. One-half course. Mr. LONGACRE.

166—Elevators and Conveyors. 1 hour. Similar to M.E. 66, and subject to same pre-requisites to entrance. One-half course. Mr. Moss.

170—Pumping Machinery. 2 hours. Similar to M.E. 70, and subject to same pre-requisites to entrance. One-half course. Mr. NICKEL.

NOTE: Full course = 10 hours a week, including outside reading, preparation, etc. Double course = more than 10 hours a week.

METALLURGY

101—General Metallurgy. 3 hours first half of first term. Professor KERN.

An introduction to general metallurgy; consideration of the methods. Object of the metallurgist, and application of physics and chemistry to the extraction, and to the treatment of the commoner metals. General classification of processes. Classification of fuels, and the selection of the most suitable fuels for certain purposes. The calorific value, and the temperature of combustion, of fuels. Preparation of charcoal and coke, and the recovery and utilization of their by-products. Artificial gaseous fuels, their preparation and metallurgical utilization. Properties of gases, and the metallurgical application of the laws of gases. Classification of furnaces, and the types of furnaces for specific purposes. Refractory materials, and their use in the construction of furnaces. Transmission of heat and the thermal efficiency of furnaces. Calculation of height, sectional areas, capacity and drafts of chimneys. Fuel economizers, and their application to metallurgical furnaces. High temperature measurements.

Third year students in Metallurgical Engineering. Fourth year students, Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4.

111—Metallurgy of Copper. 3 hours, second half of first term. Professor KERN.

The production of copper, its uses, and consumption. Properties of copper and its alloys. The ores of copper, and distribution. Characteristics of ores of the principal districts. Sampling, and preparation of copper ores for treatment, and cost of different methods of sampling. General outline of the metallurgy of copper. Roasting of copper ores; purposes; chemistry; and methods of roasting. The advantages, disadvantages, and comparative cost of roasting processes. Introduction to smelting copper ores in reverberatory, and in blast furnaces. Composition, physical properties, and characteristics of furnace products; blister copper, black-copper, mattes, speiss, slag, and flue-dust. Smelting in reverberatory furnaces; construction of reverberatory smelting furnaces, their capacity and efficiency. Converting of copper matte in reverberatory furnaces. Smelting of copper ores in blast-furnaces. Calculation of smelting furnace charges. "Pyrite" or "Raw

Ore" Smelting. Converting of copper matte by the Mahnés process. Apparatus required for converting copper matte. Refining of blister copper, black-copper, and cement-copper. Smelting of typical copper ores, producing ingot copper; the handling, and the disposition of the furnace products; cost of treatment.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 101.

118—Metallurgy of Copper. 1 hour. Professor KERN.

Advanced Course. Treatment of low-grade ores, and of copper-silver ores by leaching. Recovery of copper from mine-water. Utilization of furnace-gas for the production of sulphuric acid. Treatment of copper-nickel ores. Treatment of speiss. Metallurgical calculations of roasting and smelting operations. Application of thermo-chemistry to roasting, smelting and converting, and to calculations of furnace efficiencies. Purchasing of copper ores and fluxes.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111.

122—Metallurgy of Lead, Silver, Gold and Zinc. 3 hours. Professor WALKER.

Properties of lead, its compounds and alloys. Classification of ores. Production and uses of lead. Outline of the metallurgical treatment of lead ores. Smelting in the reverberatory furnaces; in the ore-hearth. Blast furnace practice for smelting lead ores. Roasting in hand and mechanical furnaces. Various pot-roasting processes and sintering machines. Smelting operations; construction of furnaces; calculation of charge; disposition, handling and treatment of by-products. Desilverization of lead bullion. Influence of impurities and elimination of same. Cupellation of rich lead alloys and ores. Treatment of Dore. Silver, properties, compounds, alloys, etc. Direct amalgamation of silver ores. Hydro-metallurgical processes for treatment of silver ores; Ziervogel, Patera, etc. Gold. Properties, etc. Amalgamation of gold ores. Chlorination processes. Cyaniding of gold ores; laboratory tests, and chemistry of the process; modern practice, description of existing plants. Refining and parting of gold and silver bullion. Zinc, properties, ores, etc. Calcination and roasting of zinc ores. Retorting furnaces. Manufacture of retorts; retorting practice and chemistry of same. Refining of zinc.

Third year students in Metallurgical Engineering. Fourth year students in Mining Engineering, Chemical Engineering and Chemistry. Pre-requisite: Metallurgy 111.

128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. 1 hour. Professor WALKER.

Advanced Course. Methods of receiving and sampling different classes of ore. Purchasing of ore of varying compositions. General construction of furnaces, and design of smelting plants. Organization of smelting plants; metallurgical bookkeeping, cost sheets, etc.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 122.

131—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Manufacture of iron and steel. Blast furnace. Puddling. Cementation. Crucible process. Bessemer process. Open hearth process. Statistics. Iron and steel casting. Effect of heat treatment. Effect of mechanical treatment. Malleable cast iron. Standard specifications. Constitution of iron and steel. Relation to physical properties. Change of structure with heat and mechanical treatment. Alloy steels. Corrosion.

Fourth year students in Mining, Metallurgical, Chemical Engineering, and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4. Pre-requisite or parallel: Metallurgy 101.

134—Metallurgy of Iron and Steel. 2 hours. Professors WALKER and CAMPBELL.

Introduction, literature, scheme of iron and steel manufacture. Definitions: iron, steel, cast iron, etc. Relations of carbon and iron. Development of the industry. The blast furnace, iron ores, fuels, fluxes, smelting practice, products. Processes for purification of pig iron. Manufacture of wrought iron and crucible steel. Puddling, charcoal hearths, fineries. Cementation, blister steel. Crucible process. Bessemer process, acid and basic. Siemens-Martin or Open Hearth process, acid and basic; fuels and regeneration. Defects in ingots and other

castings. Iron and steel founding. Mechanical treatment of steel, forging, rolling. Heat treatment of steel. Heat treatment of cast iron. Malleable cast iron, cupola and air furnace. Alloy steels; nickel; vanadium; manganese; chrome; tungsten, etc. Self-hardening, high-speed steels.

Practical metallography of iron and steel. Macroscopic examination. Microscopic examination of wrought iron, pipe steel, low carbon and structural steel. Shafting, etc. Medium and high carbon, rails and tires. Tool steels. Cast irons. Comparison of good with bad material. Relation between structure and properties. Corrosion. Standard specifications. Electrometallurgy of iron and steel.

Second year students in Civil, Electrical, and Mechanical Engineering. Pre-requisite: Chemistry 3 or 4 and Physics 3-4.

138—Metallurgy of Iron and Steel. 1 hour. Professor CAMPBELL.

Advanced Course. A detailed study of the constitution of iron and steel and the effects of heat and mechanical treatment upon the constituents. Discussion of the various processes of manufacture of iron and steel, alloys steels, etc. The iron and steel industry of the United States, Germany, England, and other countries. Standard methods of testing.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 131.

141—Electrometallurgy. 1 hour. Professor KERN.

Theory of the electric current, and its application in the treatment of ores, refining of metals, and production of refractory alloys. Theory of electrolysis; determination of efficiency. The solution pressure series of the metals, and its application in the refining of copper, lead, iron, nickel, antimony, tin, zinc, gold, and silver. Electrolytic refining of copper. Electrolytic refining of lead. Treatment of anode residual. Parting of silver and gold by electrolysis. Refining of gold alloys. Electrolysis of fused electrolytes; production of aluminum; treatment of sulphide ores, etc. Electric furnaces used: for smelting ores, for refining metals, and for manufacture of refractory alloys. Efficiency of electric furnaces; cost of constructing and maintaining.

Fourth year students in Mining and Metallurgical Engineering, and Chemistry. Pre-requisite: Chemistry 3 or 4 and Physics 3-4.

148—Electrometallurgy. 1 hour conference. Professor KERN.

Advanced Course. Construction of electrolytic refineries; calculations of current, and power efficiencies. Selection of most suitable electrolyte, and most economical current density. Labor-saving appliances. Electrolytic deposition of copper, lead, zinc, nickel, gold and silver from solutions obtained by leaching their ores. Production of solid deposits, and laws governing the same. Rôle of current density in the electrolysis of aqueous and fused electrolytes, and in the operation of electric furnaces. Application of thermochemical calculations to electrolytic, electro-thermic, and electric furnace operations. Calculation of efficiencies of electric furnaces and of electro-thermic operations.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 141.

151—Constitution and Properties of Alloys. 2 hours. Professor CAMPBELL.

Pyrometry and freezing point or cooling curves. Various types of curves and their meaning. Examples of the same. Constitution of the various binary alloys. Methods of manufacture of commercial alloys. Ternary alloys. The phase rule. Change of structure in the solid state, pure metals, alloys, bronze, brass, steel. Methods of metallographic research.

Fourth year students in Metallurgical Engineering. Pre-requisite: Metallurgy 111; Parallel Metallurgy 131.

155-6—Metallography. Iron, Steel and Industrial Alloys. Six lectures and 7 or more afternoons laboratory. Professor CAMPBELL.

Methods of examination. Comparison of good and bad material; wrought iron, low carbon steel, structural steel, rail steel, tool steel, etc. Examination of brasses, bronzes, bearing metals and other industrial alloys. Relation between chemical composition, physical properties and microstructure.

Course for students in Mechanical Engineering, and for special students. Pre-requisite: Metallurgy 131 or 134.

158—Advanced Course on Constitution and Property of Alloys. 1 hour. Professor CAMPBELL.

Discussion of binary alloys. Ternary diagrams with examples. The constitution of silicates, sulphides, arsenides, etc. Recent advances in Metallography.
Fourth year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 151.

62S—Summer Course in Non-Ferrous Metallurgy. Professor KERN.

For description see page 41. 1 week field work at metallurgical plants during the summer.

Instruction for this field work will be given in five one-hour conferences during the last week in April.
Third year students in Mining Engineering.

64S—Summer Course in Ferrous Metallurgy. Professor CAMPBELL.

For description see page 41. Third year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 101.

66S—Summer Course in Non-Ferrous Metallurgy. Professors WALKER and KERN.

For description see page 41. Third year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 122.

72—Metallurgical Laboratory. 10 consecutive afternoons, second term. Professor CAMPBELL and Professor KERN.

Calibration of Le Chatelier pyrometer. Cyaniding and chlorination of gold ores. Roasting of copper matte, and use of pyrometer. Desilverizing of base bullion by Parke's process. Microscopic metallography. Thermal treatment of steels.
Fourth year students in Mining Engineering.
Pre-requisite: Metallurgy 111. Parallel: Metallurgy 122.

171—Metallurgical Laboratory. 3 afternoons. Professors CAMPBELL and KERN.

Calibration and comparison of thermo-electric, optical and radiation pyrometers. Determination of the calorific power of fuels by the Mahler-Berthelot calorimeter. Microscopic study of metals and alloys. Thermal and mechanical treatment of steels. Roasting of copper matte, and use of pyrometer. Production of blister copper by the reaction process. Refining of blister copper. Desilverization of base bullion by Parke's process. Cyaniding of gold and silver ores. Chlorination of gold ores. Electrolytic refining of copper and lead bullion. Fusibility of slags and refractory materials.
Fourth year students in Metallurgical Engineering. Parallel: Metallurgy 101 and 111.

172—Metallurgical Laboratory. 2 afternoons. Professors WALKER, CAMPBELL and KERN.

Special investigation in some subject or subjects in either ferrous or non-ferrous metallurgy. Subjects are similar to those noted under the head of Met. 201-202.
Fourth year students in Metallurgical Engineering.
Pre-requisite: Metallurgy 171.

173-174—Metallurgical Laboratory. Professors CAMPBELL and KERN.

Special work along the lines indicated under the head of Metallurgy 201-202. This work is intermediate between that of Metallurgy 171 and 201-202 and is designed for those desiring to take an advanced metallurgical laboratory course without confining themselves to special research work.
Pre-requisite: Metallurgy 171.

175—Metallurgical Investigation. 1 hour conferences. Professors WALKER and CAMPBELL.

Fourth year Metallurgical Engineers. Pre-requisite: Metallurgy 122. Pre-requisite or parallel: 131, 141.

77—Metallurgical Plant Construction. Professor WALKER.

General design of metallurgical plants and problems entering into the construction of same.

Special work is assigned to each student, which is carried on under direct and constant supervision in the drafting room and laboratories. The experience gained in visits to metallurgical plants is brought into practical use.

Fourth year Metallurgical Engineers. Pre-requisite: Drafting 3-4, 7-8; Civil Engineering 53; Metallurgy 122, 64S and 66S.

81—Assaying. 2 hours, 3 afternoons. Professor HALL.

Ores and metallurgical products. Text-books: Fulton's *Manual of Assaying.* The assays included in this course are: Preliminary (reagents. etc.): lead ores; gold and silver ores; pure and impure, including galena, stibnite, arsenopyrite, blende, pyrite, tellurides, etc.; mattes and tailings; corrected assays and cyanide solutions; gold, silver and lead bullions.

Third year students in Mining Engineering and Metallurgical Engineering. Pre-requisites: Chemistry 3 or 4 and 61 or 62; Mineralogy 1-2 or 7-8.

82S—Summer School in Assaying. Professor HALL.

182—Assaying. 2 lectures or recitations. 2 afternoons. Professor HALL.

A short course covering practically the same ground as Met. 81.

Third year students in Chemical Engineering and Chemistry. Pre-requisites: Chemistry 3 or 4 and 61 or 62; Mineralogy 1-2 or 7-8.

188—Assaying. Advanced course. Professor HALL.

For those desiring to take special work in assaying.

Pre-requisite: Metallurgy 81 or 182.

Graduate Courses

Special courses, consisting of original research, will be arranged for graduate students according to their individual needs and abilities. Most of these researches will consist of work in the departmental laboratories, but others will consist of study, and still others of work in industrial establishments.

The following list shows what subjects are suited to these courses:

201-202 (*a*)—Advanced work on some problem in general metallurgy, as for example:

In Calorimetry: Determination of the calorific power of fuels, or testing some law in calorimetry;

In Pyrometry: Determination of the temperatures of metallurgical and other industrial high-temperature operations;

On Refractory Materials: Their resistance to heat and corrosion; their tendency to slack; their contraction and expansion, etc.;

On Slags: Their formation temperature, melting points, flowing points, and their density and viscosity when molten;

(*b*)—In the Metallurgy of Copper:

The chemistry of roasting processes, such as the elimination of arsenic and sulphur; chloridizing and sulphate roasting, etc.

The reactions of smelting processes;

Wet methods of extraction;

(*c*)—In the Metallurgy of Lead, Silver, Gold, etc.:

The blast-roasting of sulphides, and others mentioned above under (*b*);

(*d*)—In the Metallurgy of Iron and Steel:

The effect of various constituents on Iron and Steel.

The heat and mechanical treatment of Iron and Steel; effect on physical properties and microstructure.

The study of alloy steels and the effect of heat treatment.

Case hardening, etc.

(*e*)—In Electrometallurgy: Testing electrometallurgical principles, refining, extraction and depositing process;

(*f*)—On Alloys: The constitution and properties of alloys, embracing a microscopic, pyrometric and mechanical or physical examination with a correlation of the results;

(*g*)—In Metallography: Metallography of iron, steel, industrial alloys or metallurgical products, as mattes, slags, etc.

Pre-requisite for 201-202: Metallurgy 122, 131, 141 and 171, or equivalent.

MINERALOGY

1-2—Descriptive and Determinative Mineralogy. 3 hours lectures throughout the year, 6 hours laboratory first term, 3 hours laboratory second term. Professors Moses, Luquer and Assistants.

The elements of crystallography. The blowpipe analysis of ores and other substances. The study of the important minerals, the purpose being: 1st. Sight recognition of average specimens of all common or economically important species; 2d. Rapid determination of the less characteristic specimens by simple tests; 3d. Familiarity with economic characters.

Pre-requisite: Entrance requirements in Chemistry and Physics. Prescribed course for students in Mining.

5—The Minerals of Building Stones. 2 hours lectures and 1 afternoon laboratory. Professor Luquer and Assistants.

Study of common species, their properties, methods of determination, and their economic effect on building stones.

Pre-requisite: Entrance Chemistry and Physics. Prescribed for students in the course of Civil Engineering.

6—Optical Mineralogy. In sections, 2 afternoons per week for first seven weeks of term. Professor Luquer and Assistant.

Principles, apparatus, and distinguishing characters of minerals in thin sections. Consists principally in the determination of minerals in rock sections by the aid of the polarizing microscope. Supplements Courses 5, 1-2 and 7-8 and is preliminary to Geology 4 (petrography).

Pre-requisite: Course 5, or part of Course 1-2, or 7-8, or the equivalent. Prescribed for students in Mining and Metallurgy.

7-8—Descriptive and Determinative Mineralogy. 3 hours lectures, 3 hours laboratory. Professors Moses, Luquer and Assistants.

Modification of Mineralogy 1-2. Lectures identical, laboratory work condensed.

Prescribed course for students in Metallurgy.

Prerequisite: Entrance Chemistry and Physics.

10—Mineralogy and Crystallography. 2 hours lectures and 3 hours laboratory. Professor MOSES and Assistant.

Supplements Mineralogy 15-16 by first, further instruction in sight recognition of increased number of species; second, crystal measurement and determination of constants; third, the study and determination of minerals and crystals with the polarizing microscope.

Pre-requisite: Mineralogy 15-16. Prescribed for third-year students in Chemistry.

15-16—Determinative Mineralogy. 3 hours laboratory. Professor MOSES and Assistants.

Sight recognition and determination of minerals important in the chemical industries.

Pre-requisite: Entrance Chemistry and Entrance Physics. Prescribed for students in Chemistry and Chemical Engineering.

MINING

Undergraduate Courses

51—Excavation and Tunneling. 3 hours, third year. Professor PEELE.

Excavation of earth: tools and methods employed, support of excavations, special methods for quicksand and other water-bearing material; steam shovels and other mechanical excavators; handling and transportation of excavated material; comparative costs. Explosives: black powder, nitro-glycerine and its compounds, and other high explosives; their composition, manufacture, and use. Excavation of rock: methods of drilling and blasting mammoth blasts, submarine blastings. Railroad tunnels: methods of driving and timbering; handling and transportation of excavated material; drainage and ventilation; lining of tunnels, subaqueous tunnels. Mine tunnels; examples from practice; sizes, details of driving, timbering, rates of advance and costs.

Required of students in the course of Mining Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry, and Physics.

52—Boring and Shaft Sinking. 2 hours, third year. Professor PEELE.

Boring: methods and appliances for small depths and for deep boring; rod boring and oil-well or churn drill method; boring with core drills, for prospecting and other purposes; survey of bore-holes. Shaft sinking: methods and tools employed in rock and in soft material, sinking linings or drop-shafts, freezing and other special methods of sinking in soft water-bearing formations; drainage of shafts; handling and hoisting of excavated material. Shaft timbering, walling, tubbing, and other forms of lining. Costs of shaft sinking.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51.

53—Excavation, Tunneling, Boring and Shaft Sinking. 2 hours, second year. Mr. JUDD.

A condensation of courses 51 and 52, in which attention is given only to those operations that are of special interest to the civil engineer. Excavation and transport of earth for structural purposes and railroad grading; steam shovels and dredges. Explosives. Excavation of rock; methods of drilling and blasting; submarine blasting; railroad tunnels; quarrying; testing for foundations in earth, rock and watery material; well drilling; shaft sinking by usual and special methods.

Required of students in the course of Civil Engineering. Pre-requisite: Entrance requirements in Mathematics, Chemistry and Physics.

54—Exploration, Development, and Methods of Working. 3 hours, third year. Professor MUNROE.

Mineral deposits, characteristics of beds, masses, veins, and other deposits, and the irregularities and disturbances to which they are subject, as affecting the work of exploration and mining. Examination and survey of mineral properties; relation of topography to geological structure; construction of maps and sections; and tracing of probable outcrops as a guide to exploration. Prospecting by ditches, pits, and deep boring. Development; choice of methods; location of openings. Working of deposits and support of excavations; theoretical considerations, methods of breaking ground in coal and metal mining, and support of mine excavations by

pillars of mineral, by timbering, by masonry, and by rock filling; methods of working applicable to deposits of different thickness, inclination, and character. Coal mining; vein mining; working of thick deposits and soft-ore bodies. Salt mining. Surface working. Hydraulic mining and gold dredging.

Required of students in the courses of Mining and Metallurgical Engineering. Pre-requisite: Geology 5-6. Pre-requisites or parallels: Geology 105-106, Mining 51 and 52. Accepted together with Mining 81 and 82, or with Mining 56 and 91, as a minor for the degree of A.M.

56—Mine Engineering. 3 hours, fourth year. Professor MUNROE.

Ventilation; air of mines; mine gases; methods of ventilation; control and measurement of air currents. Drainage: sources of mine waters; methods for the control and raising of water; dams; drainage levels. Water supply. Surface handling and transportation; arrangements for loading and unloading cars and vessels, and for storing of minerals. Mineral railroads. Common roads. Accidents to men in shafts, levels and working places; fire-damp and dust explosions; mine fires; inundations; rescue and relief of men. Mine surveying, mine maps and models. Examination, sampling and valuation of mines.

Required of students in the course of Mining Engineering. Pre-requisites or parallels: Mining 54 and 71-72, Civil Engineering 76 and 28. Accepted together with Mining 54 and 91, as a minor for the degree of A.M.

71-72—Mine Plant. 3 hours, fourth year. Professor PEELE.

Description and critical discussion of the machinery and appliances employed in the equipment of mines; design, erection and care of plant. Hoisting: engines, drums, wire rope, skips and cages, head-frames; calculation of power required and methods of equalizing the load on the engine; shaft-sinking plant, over-winding. Drainage: buckets, tanks and hand-pumps; Cornish and direct-acting underground pumps; operation of pumps by electricity, compressed air, and hydraulic power. Centrifugal pumps. Ventilation: underground furnaces, positive blowers, and centrifugal fans; theory and efficiencies of fans. Air compressors: simple and compound (stage) compression; methods of dealing with heat of compression; conveyance of compressed air in pipes; reheating; operation of machinery by compressed air; efficiencies. Machine drills; coal-mining machines or coal-cutters. Handling mineral in working places. Mine cars; arrangement and construction of tracks. Underground haulage; hand tramming; mule haulage; gravity roads; steam, compressed-air, and electric locomotives; rope haulage; efficiencies; comparison of systems of haulage.

Required of students in the course of Mining Engineering. Pre-requisite: Mining 51, 52 and 54, and Mechanical Engineering 13-14. Accepted together with Mining 73 and 75, as a minor for the degree of A.M.

73—Mine Constructions. 1 hour, fourth year. Professor PEELE.

Building-stones; bricks; limes; cements and concretes. Foundations in various soils; retaining walls; masonry and timber construction, with special reference to mine work; mine buildings; trestles; ore-bins.

Required of students in the courses of Mining and Metallurgical Engineering. Accepted together with Mining 71-72 and 75, or with Mining 81, 82 and 75, as a minor for the degree of A.M.

75—Design of Mine Plant. 4 afternoons, fourth year. Professors PEELE and KURTZ and Mr. JUDD.

The students are assigned problems in the design and construction of mine plant, in connection with the development of a mine. This work supplements the lectures on the design of mining machinery, involving reading and study, and the preparation of working drawings, covering certain portions of the plant, together with bills of material, specifications, and estimates. As these drawings are intended to accompany and illustrate in part the graduating theses or projects, the designs are made in accordance with the subjects and conditions therein assigned. The work is done under constant supervision and advice in the draughting-room.

Required of students in the course of Mining Engineering. Pre-requisite: Drafting 3-4, 7-8, Civil Engineering 53, Mining 59. Parallel: Mining 71-72. Accepted together with Mining 71-72 and 73, or with Mining 81, 82 and 73, as a minor for the degree of A.M.

77-78—Graduating Thesis or Project. Professor PEELE.

Mining Thesis

The subjects for the graduation theses are assigned during the third year, and are made a part of the regular course of instruction. The subject given in each case is the problem of the opening and development of a mine, supposed to be

located in some well-known mining district, and for which certain definite conditions as to size and character of ore body, amount of water to be pumped, and quantity of ore to be mined, are assumed. During the summer field work in mining the student incidentally obtains data for his thesis work. This information is supplemented by study of books and technical literature. During the fourth year he decides upon the proper methods for opening, developing, and working the property; and makes estimates of the plant, machinery and capital required, the cost of working, and the probable profits. He also works out in detail certain portions of the proposed mine plant, and prepares a set of working drawings, bills of materials and specifications therefor. This work, done under the supervision of competent instructors, constitutes both a review and a series of practical applications of the preparatory studies and enables the students to discover and remedy their deficiencies, giving them confidence in their ability to work out similar problems later.

Required of students in the course of Mining Engineering. Pre-requisites or parallel: All the required courses in Mining.

80—Mill Constructions. 1 hour, fourth year. Professor KURTZ.

Installation and operation of mechanical power transmission and auxiliary machinery in works for the mechanical treatment of minerals. Dealing with shafting, bearings, pulleys, belting, rope drives, gearing, etc.

Pre-requisite: Mechanical Engineering 13-14.

81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. 4 hours, fourth year. Professor MUNROE.

The general principles and theory of dressing; preliminary operations; hand dressing; cleansing; crushing; jigging with and without preliminary sizing; slime concentration; magnetic and electro-static separation; oil and flotation processes; milling of gold ores; descriptions of typical dressing works and coal-washing plants in this country and abroad.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mineralogy 1-2, Physics 3-4, and Mechanics 102. Accepted together with Mining 54 and 82, or with Mining 82, 73 and 75 as a minor for the degree of A.M.

82—Ore-dressing Laboratory. Afternoon work for three weeks, fourth year. Professors MUNROE and KURTZ and Mr. JUDD.

Mechanical testing of ores by laboratory methods; working tests with simple apparatus; adjustment and operation of concentrating machines.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mining 81. Accepted together with Mining 54 and 81, or with Mining 81, 73 and 75, as a minor for the degree of A.M.

91—Mine Administration. 2 hours, fourth year. Professors MUNROE and KURTZ.

Administration, organization, and business management, mine accounts, and cost sheets.

Required of students in courses of Mining and Metallurgical Engineering.

Pre-requisite: Mining 54. Accepted together with Mining 54 and 56, as a minor for the degree of A.M.

94—Mining Law. 2 hours, fourth year. Professor KURTZ.

General principles of real estate law. Historical review of mining laws of different countries. Federal laws, concerning locations on public lands of the United States. State and territorial mining laws.

Pre-requisite: Civil Engineering 27, Mining 54.

Summer Courses

58—Summer Class in Mine Surveying is held in June, at a mine in a near locality, and lasts one week. Professors MUNROE and KURTZ and Mr. JUDD.

Pre-requisite: Civil Engineering 27.

59—The Summer Courses in Practical Mining. Professors PEELE and KURTZ and Mr. JUDD.

Held in June and July, at some mine or mines selected for the purpose, in the vacation between the third and fourth years, and lasts six weeks (for details see page 40).

Pre-requisite: Mining 51, 52 and 54, Civil Engineering 15 and 27, Mechanical Engineering 13-14, and Geology 105-106.

Graduate Courses

Special courses, consisting of personal instruction, reading and experimental investigation, will be arranged for advanced students according to their individual needs and ability. These investigations will be made at mines and dressing works either in connection with the Summer class or elsewhere as assigned, with additional work, as required, in the library and in the laboratories of the department. The time required is governed by the rule that a full course should occupy 10 hours (outside reading and study included) per week for a half year. Any of the following may be offered for the degree of A.M. by students who have had the appropriate pre-requisites:

101-102—Mining and Ore Dressing. Mining 54, 81 and 82, with laboratory work and reading as required. Two full courses.

Under the regulations for the degrees of A.M. and Ph.D. the following courses may be offered by graduate students who have had all the undergraduate courses in mining or their equivalent.

201-202—Methods of Mining. Critical study of methods used in some mining region, or for a certain class of deposits; output per man, amount of timber and explosive required, and other details affecting cost. Study of conditions as determining choice of method. Determination of loss of mineral in mining. Accidents to men. Two full courses.

203-204—Mining Plant. Critical study of rock drilling, or coal cutting, or hoisting, or haulage, or ventilating plant at some mine or mines. Determination of efficiency and conditions affecting same. Two full courses.

207-208—Ore Dressing. Critical study of some detail of the ordinary dressing methods, crushing, or screening, or classification, or jigging, or slime treatment, or dry concentration, or magnetic separation, or milling of gold or silver ores, or mechanical preparation of coal. Determination of efficiency, and of conditions essential to success. Two full courses.

213-214—Economic Studies in Mining. Study of existing conditions affecting the production and cost of some mineral or metal, as, for example, anthracite coal, copper, or gold. Two full courses.

PHYSICAL EDUCATION

B1-B2—Physical Education. 6 lectures on public and personal hygiene during January. 2 hours a week of athletic and gymnastic exercises during the whole year, except January. Students must report at the gymnasium office within two days after the opening of the semester and fill out cards indicating the branch of athletics in which they intend to satisfy the requirements of the course. Professor MEYLAN, Mr. KIRKPATRICK and Assistants.

Note—Students getting a grade of B or better in Physical Education A are not required to take **Physical Education B1-B2.**

PHYSICS AND MECHANICS

Mechanics 1—Statics. 2 hours.

Class is divided into small sections for recitations. Coplanar Statics is treated by both algebraic and graphical methods. Text: Maurer's *Technical Mechanics.*

Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 3-4—General Physics: Mechanics, Wave-Motion, Heat and Light. 3 lectures and 2 recitations.

Mechanics—Newton's laws of motion; accelerated linear and angular motions; dimensions; systems of weights and measures; energy, work, power; transformations of energy; conservation of energy; curvilinear motion with applications; gravitation; linear and angular simple harmonic motion; pendulum; wave-motion; forced vibrations and resonance; hydrostatics, molecular mechanics.

Heat—Nature of heat; expansion; thermometry; calorimetry; specific heat; mechanical equivalent of heat; change of state; saturated vapors and hygrometry; continuity of state; conduction; convection; radiation.

Light—General discussion of wave-theory; reflection; refraction; total reflection; index of refraction and measurement; lenses; dispersion; spherical and chromatic aberration; optical instruments; photometry; color; fluorescence and phosphorescence; radiant energy; spectrum analysis; polarization of light.

Required of all first year students in Engineering. Pre-requisite: Entrance Physics and Entrance Mathematics (including Trigonometry).

Physics 5—Electricity. 3 lectures and 2 recitations. Professor WENDELL and instructors.

Phenomena of electrostatics; capacity and condensers; electrometers; current electricity and methods of production; Ohm's law with applications; Joule's law with applications; thermo-electricity; magnetic action of currents with applications; electrical units; electro-magnetic induction; inductance.

Required of all second year students in Engineering. Pre-requisite: Physics 3-4.

Physics 43-44—Physical Laboratory. 3 consecutive hours a week throughout the year. Professor WENDELL, Dr. MORSE, Dr. WEINRICH, Mr. SEVERINGHAUS, Dr. STIFLER, Mr. SCOTT, Mr. BRAININ, Mr. MURPHY, Mr. ULREY.

This course consists of quantitative experiments with reports in mechanics, light, heat, electricity, and magnetism. Methods of computation, plotting and the precision of measurements are discussed in connection with the experiments.

Pre-requisite: Physics 3-4. Parallel: Physics 5.

Physics 55—Physical Measurements. 2 hours. Dr. STIFLER.

Critical discussion of physical measurements and computations.

Pre-requisite: Physics 3-4. Parallel: Physics 5.

Mechanics 102—Mechanics. 5 hours. Professors BURNSIDE, SCHROEDER and WEBB and Mr. WHITTEMORE.

This course is a continuation of Mechanics 1, using the same text book. The class is divided into small sections for recitations. Statics is completed; centers of gravity and moments of inertia of areas treated with aid of calculus; displacement, velocity, acceleration, motions of translation and rotation, work and energy, power, efficiency, impulse and momentum are all treated with special reference to engineering problems.

Required of all second year students in Engineering. Pre-requisite: Mechanics 1, Physics 3, and Mathematics 64-65.

Mechanics 105—Thermodynamics. 2 hours. Professors WILLS and PEGRAM.

An idea of the nature of the course may be obtained from the following topical headings: The nature of heat; thermometry; calorimetry; heat and work diagrams; the First Law; applications to gases, perfect and actual; the work of Carnot; the Second Law; the Kelvin absolute scale of temperature; the combination of the two laws; application to the problem of change of state; the properties of saturated

and superheated steam; theory of the "plug experiment"; the flow of fluids from orifices.

Pre-requisite: Physics 4 and Mechanics 102.

Mechanics 107-108—Theory of Electricity and Magnetism. 2 hours first half-year, 3 hours second half-year. Professor WILLS.

The fundamental principles of electricity and magnetism are developed and discussed with particular reference to the bearing which they have in relation to the science of electrical engineering. The course concludes with an introduction into the theory of alternating currents.

Pre-requisite: Physics 5 and Mathematics 64-65.

Mechanics 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits. 4 hours first half-year, 3 hours second half-year. Professor PUPIN.

Pre-requisite: Mechanics 107-108.

Physics 52—Conduction of Electricity in Gases. 5 2-hour lectures. Professor DAVIS.

Mathematical Physics 201—Vector Analysis and Mathematical Introduction. 4 hours. Professor WILLS.

Mathematical Physics 203-204—Partial Differential Equations of Physics. 2 hours. Dr. WEBB.

Laplace's Equation; Poisson's Equation; Equation of Heat Conduction; Telegrapher's Equation; Fourier's Series; Spherical Harmonics; Bessel's Functions.

Mathematical Physics 206—Mechanics. 4 hours. Professor WILLS.

An advanced course on Mechanics developed with special reference to the general methods of d'Alembert, Lagrange, Jacobi and Hamilton.

Mathematical Physics 208—Elasticity. 2 hours. Professor WILLS.

Mathematical Physics 215-216—Electricity and Magnetism and Electro-Magnetic Theory of Light. 2 hours. Professor PUPIN.

Mathematical Physics 223-224—Recent Advances in Electrical Theory. 2 hours. Professor PUPIN.

For other courses in experimental and mathematical physics the student is referred to the *Announcement of the Division of Mathematical and Physical Science.*

SHOP WORK

The shop work is done in the Macy Building, which has full modern equipment, including the best types of improved machine tools for wood working and metal working in shops that provide for groups of twenty to twenty-four students to a section.

Shop work in wood is planned to lead up to pattern making and foundry work. The equipment includes benches for joinery and pattern making with the necessary hand tools and individual speed lathes for wood turning, a motor-head speed lathe of large size, 36-inch band saw and trimmers of the most recent type. There are also available for working up stock and special projects a saw bench, surfacer, jointer, mortising machine, all of the latest type.

Shop work in metal includes foundry, forging and machine-shop

practice. The foundry contains molding benches for twenty students, and necessary tools for all kinds of bench work in snap flasks, floor molding, loam work, and the application of sweeps to the making of molds, together with melting pits for the melting of brass and bronzes and a cupola for melting cast iron. In the forge shop there are twenty forges with anvils, tools and vises, a 30-pound Bradley power hammer and a 400-pound Billings and Spencer drop-press. The machine shop contains lathes, swinging from twelve to twenty inches, planers, drill-presses, universal milling machines, and grinding machines, with examples of direct-connect motor and belt drives for each. A Jones and Lamson flat turret-lathe and a Warner and Swasey screw machine are used for demonstrating modern methods of economical repetition production. In conjunction with all the shops there is a well-equipped tool-room, the attendance record is kept by a time-keeper's recording clock, and the organization and atmosphere of a commercial shop are aimed at.

1—Wood-turning and Pattern-making. 2 afternoons. Mr. CONSTANTINE.

Shopwork, demonstrations and shop visits. The construction of typical patterns and core boxes, solid, split and piece, involving the use of bench tools and turning lathe. Second year students in Mechanical Engineering.

2—Molding and Foundry Practice. 1 afternoon. Professor SLEFFEL.

Shopwork, demonstrations and shop visits. Bench molding with type patterns, swept work in green sand and loam and molding in dry sand. Second year students in Mechanical Engineering.

10S—Machine Work. Mr. WALSH.

As below. Mechanical Engineering. Section I, three weeks in June; Section II, three weeks in September. Second year.

11—Machine Work. 2 afternoons. Mr. WALSH.

Shopwork, demonstrations and shop visits. Practical work with the lathe, planer, drill, shaper, milling machine, grinder and turret lathe. Assembling, erection and rigger's work. Third year students in Mechanical Engineering.

Pre-requisite: Shopwork 10S.

12—Forging. 2 afternoons. Professor SLEFFEL.

Shopwork, demonstrations and shop visits. Management of fire, shaping, drawing, upsetting, swaging, welding, tempering and die-forging. Work on drop and helve hammers. Second year students in Mechanical Engineering.

13-14—Machine Work. 1 afternoon. Mr. WALSH.

As above. Second year students in Electrical Engineering.

15—Forging and Foundry Practice. 1 afternoon. Professor SLEFFEL.

As above. Second year students in Civil Engineering.

16—Machine Work. 1 afternoon. Mr. WALSH.

As above. Second year students in Civil Engineering.

18S—Pattern-making, Forging, and Machine Work. Three weeks in June. Professor SLEFFEL, Mr. CONSTANTINE and Mr. WALSH.

As above. Second year students in Chemical Engineering.

SCHEDULE OF PRE-REQUISITES FOR SUBJECTS UNDER THE FACULTY OF APPLIED SCIENCE

Subject	Pre-requisite
Astronomy	
105—Geodesy. (For C. E.)	Math. 64-65 (Differential and Integral Calculus)
106—Geodesy. (For C. E.)	Astron. 105 (Geodesy)
107S—Geodetic Surveying (For C. E.)	Astron. 106 (Geodesy)
Botany	
7—Growth and Character of Timber	
Chemistry	Pre-requisite
101-102—Advanced Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis) Chem. 163-4 (Quantitative Analysis)
121-122—Physical Chemistry	Chem. 3 or 4 (General Inorganic); 61 or 62 (Quantitative Analysis) Phys. 3-4-5 (Elementary Mechanics and General Physics) Math. 64-65 (Differential and Integral Calculus)
125-126—Physical Chemistry	Chem. 121-122
41-42—Organic, lectures	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis)
43M—Organic laboratory	Chem. 3 or 4 (General Inorganic) and 61 or 62 Chem. 41-42 (Organic) or parallel Physics 3-4
141-142—Organic, general	Chem. 41-42-43M (Organic), 61 or 62 Chem. 65 or 66 (Quantitative Analysis, Inorganic)
143-144—Organic, conferences	Chem. 141-142 (Organic) or parallel, Physics 3-4
153-154—General Organic Chemistry	41-42, or parallel 43M
49—Advanced Organic (For Chem. E.)	Chem. 41-42 (Organic)
65—Quantitative Analysis Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
66—Quantitative Analysis Inorganic	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Anaylsis)
163-164—Quantitative Analysis	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
111-112—Theory of Inorganic Analysis	Chem. 101-102 (Advanced Inorganic) Chem. 121-122 (Physical Chemistry)
171—Organic Analysis	Chem. 163-164 (Quantitative Analysis) Chem. 41-42 (Organic) Chem. 161-162 (Quantitative Analysis, Inorganic)
175—Food Analysis	Chem. 41-42, 161-162
176—Chemistry of Food and Nutrition	Chem. 41 (Introductory Organic)
76—Microscopical Analysis	Chem. 65
78—Sanitary Biological Analysis	Chem. 65, 76
79—Sanitary Bacteriological Analysis	Chem. 65, 76
81-82—Industrial Chemistry, general course	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis)
83—Industrial Chemistry, special course	Chem. 81-82 (Industrial Chemistry) and Chem. 41 (Elementary Organic)
84—Food Chemistry	Chem. 3 or 4 (General Inorganic) Chem. 81-82 or 41-42
88—Industrial Chemistry, laboratory practice	Chem. 3 or 4 (General Inorganic) Chem. 41-42 (Elementary Organic) Chem. 163-4 (Quantitative Analysis)
89—Industrial Chemistry, laboratory practice	Chem. 61 or 62 (Qualitative Analysis)

Subject	Pre-requisite
95-96—Industrial Chemistry	Chem. 3 or 4 Chem. 61 or 62 Chem. 41-42 Chem. 65 or other Quantitative
197—Chemical Factory Management	
198—Chemical Factory Management	
80a—Factory Inspection. (For Chem. and Chem. E.) (Second Year)	
80b—Factory Inspection and Summer Factory Work. (For Chem. E.) (Third Year)	
181 or 182—Practical Electro-Chemistry	Chem. 3 or 4 (General Inorganic) Chem. 61 or 62 (Qualitative Analysis) Chem. 65 (Quantitative Analysis)
183-184—Industrial Electro-Chemistry	Chem. 3-4 (General Inorganic) Chem. 65 (Quantitative Analysis, Inorganic)

Civil Engineering

2—Theory of Surveying	
15—Surveying (between First and Second Years)	C.E. 2 (Theory of Surveying)
21—Highway Engineering	
23—Theory of Railroad Surveying	C.E. 15 (Surveying)
25—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
26—Surveying (between Third and Fourth Years)	C.E. 25 (Surveying)
C.E. 26a—Limnology	
27—Surveying (between Second and Third Years)	C.E. 15 (Surveying)
28—Surveying (between Second and Third Years)	Chem. 78-9. C.E. 23 (Theory of Railroad Surveying)
51-52—Theory of Railroad Surveying	C.E. 27 (Surveying) C.E. 15 (Surveying)
53-54—Elasticity and Resistance of the Materials of Engineering	Mech. 102 (Analytical Mechanics)
57a—Statistics and Interpretation of Water Analysis	Chem. 78 (Sanitary Biological Analysis) Chem. 79 (Sanitary Bacteriological Analysis)
57b—Drainage of Marshes and Lowlands	C.E. 59 (Sanitary Engineering)
58—Masonry Structures	Mech. 102 (Analytical Mechanics) Min. 5 (Minerals of Building Stones)
59—Sanitary Engineering	Chem. 82 (Industrial Chemistry)
61—Analytical Theory of Trusses	Mech. 102 (Analytical Mechanics)
62—Graphic Statics	Mech. 102 (Analytical Mechanics)
64—Graphic Statics (abridged course)	Mech. 102 (Analytical Mechanics)
71—Surveying (between Third and Fourth Years)	C.E. 51-52 (Theory of Railroad Surveying)
75—Hydraulics	C.E. 25 (Surveying) Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
76—Hydraulics. (For E.M.) (C.E. 75 abridged)	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
77—Hydraulics. (For E.E.)	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
78—Hydraulics. (For Chem. E. and M. E.)	Math. 64-65 (Calculus) Mech. 102 (Analytical Mechanics)
85—Foundations	C.E. 58 (Masonry Structures) Geol. 18 (General Geology)
87-88—The Design and Construction of Bridges, Roofs and Buildings. (For Sanitary Engs.)	C.E. 53-54 (Elasticity and Resistance of the Materials of Engineering) C.E. 61 (Analytical Theory of Trusses) C.E. 62 (Graphic Statics)
89-90—Railroad Engineering	C.E. 71 (Surveying)
94—Design and Construction of Sewers, and River and Harbor Improvements	C.E. 75 (Hydraulics) C.E. 59 (Sanitary Engineering) C.E. 26 (Surveying)
96—Principles of Hygiene, Sanitary Science and Public Health	Chem. 78 (Sanitary Biological Analysis) Chem. 79 (Sanitary Bacteriological Analysis) C. E. 59 (Sanitary Engineering) 57a (Statistics and Interpretation of Water Analysis) 57b (Drainage of Marshes and Lowlands)

Subject	Pre-requisite
97—Water-Supply and Irrigation Engineering 99-100—Graduation Thesis	C.E. 26 (Surveying) C.E. 59 (Sanitary Engineering) C.E. 75 (Hydraulics)
Drafting	
1 or 2—Elements of Mechanical Drafting	
3 or 4—Descriptive Geometry	
5 or 6—Graphics	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
7 or 8—Structural Drafting	Draft. 1 or 2 (Elements of Mechanical Drafting) Draft. 3 or 4 (Descriptive Geometry)
Economics	
2—Introduction to Economics	
Electrical Engineering	
2—Elements of Dynamo Electric Machinery	Phys. 3, 4 and 5 (Elements of Electrical Engineering)
4—Electric Distribution (For E.M. Met.E. and C.E.) *Parallel* E.E. 72 (Direct Current Laboratory)	E.E. 2. (Elements of Dynamo Elect. Mach'y) Phys. 5
52—Design of Direct Current Machinery *Parallel* E.E. 174 (Direct Laboratory)	E.E. 2 and 101 (Elements of Dynamo Elect. Machinery)
54—Design of Alternating Current Machinery *Parallel* Mech. 110 (Th. of Variable Currents) and E.E. 175-176	E.E. 52, 103 and 105, Mech. 108
72—Direct Current Laboratory *Parallel* E.E. 4 (Electric Distribution)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43-44 (Phys. Laboratory)
73—Direct Current Laboratory. (For M.E.) *Parallel* E.E. 101 (Dynamo and Motor Practice)	E.E. 2 (Elements of Dynamo Elect. Mach'y) Phys. 5 (Electricity and Magnetism) Phys. 43-44 (Phys. Laboratory)
75—Alternating Current Laboratory. (For E.M. and M.E.) (Short course)	E.E. 4 or 104 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
76—Alternating Current Laboratory. (For C.E.)	E.E. 4 or 104 (Electric Distribution) E.E. 72 (Direct Current Laboratory) *or* E.E. 73 (Direct Current Laboratory)
98—Thesis (Optional) *Parallel* Subjects of Fourth Year	All courses
101—Generator and Motor Practice *Parallel* E.E. 73 *or* 173-174 (Direct Current Laboratory)	E.E. 2 (Elements of Dynamo Elect. Mach'y) and Phys. 5
103—Electric Motors. (For E.E.)	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
103A—Electric Motors. (For M.E.)	E.E. 104 (Electric Distribution) E.E. 73 (Direct Current Laboratory)
104—Electric Distribution	Phys. 5 and E.E. 2 and E.E. 101
105—Alternating Current Engineering. (For E.E.)	E.E. 104 (Electric Distribution) E.E. 101
105A—Alternating Current Engineering. (For M.E.)	E.E. 104 (Electric Distribution) E.E. 101 (Dynamo and Motor Practice)
106—Electric Plants	E.E. 105 (A.C.Eng.) E.E. 104 (Electric Distribution)
108—Plant Inspection *Parallel course* E.E. 106	E.E. 173-174 E.E. 104
109-110—Telegraphy and Telephony, E.E. 104	For E.E. students E.E. 104, 173-174
112—Electric Railways 173-174—Direct Current Laboratory *Parallel* E.E. 101 (Dynamo and Motor Practice)	For C.E. students E.E. 4, 72 and 75 E.E. 2 (Elements of the Dynamo) Phys. 5 and 43-44

Subject	Pre-requisite
175-176—Alternating Current Laboratory	E.E. 104 (Electric Distribution) E.E. 173-174 (Direct Current Laboratory)
Parallel Mech. 109 (Theory of Alternators and Transformers), Mech. 110 (Theory of Variable Currents), E.E. 103 (Electric Motors) and 105 A. C. Eng.	
177—Instrument Laboratory	E.E. 173-174 (Direct Current Laboratory) E.E. 104 (Electric Distribution

Geology

4—Petrography	Min. 6 (Optical Mineralogy)
5-6—General Geology	Min. 1-2 (Descriptive and Determinative Mineralogy) Parallel course
16—Index Fossils	Geol. 5-6 (General Geology)
18—General Geology	Min. 5 (Minerals of Building Stones)
51—Principles of Geology	Geol. 5-6 (General Geology) *or* Geol. 18 (General Geology)
52—Discussion of Secondary Structural Features	Geol. 5-6 (General Geology) *or* Geol. 18 (General Geology)
101—Applied Petrography	Geol. 4 (Petrography)
102—Petrography of the Ores	Geol. 4, 101, 105-106 (Petrography and Economic Geology)
105-106—Economic Geology	Geol. 5-6 (General Geology)
107-108—Invertebrate Palæontology	Antecedent work in Geology
110—Geological Examinations and Surveys	Geol. 105-106 (Economic Geology)
112—Field Geology	Geol. 5-6 (General Geology) Geol. 105-106 (Economic Geology) *desirable, not prerequisite*
201-202—Petrology	Geol. 4 (Petrography)
205-206—Comparative Geology	Geol. 5-6 (General Geology) Geol. 16 (Index Fossils)

Law

2—Business Law	

Mathematics

1 (or 2)—Algebra	Entrance Mathematics
64 (or 67)—Calculus	Math. 3 (Anal. Geometry) or Math. 4
3 (or 4)—Analytical Geometry	Entrance Mathematics
65 (or 68)—Calculus	Math. 3 or 4 (Anal. Geometry) and Math. 64 or 67 (Calculus)

Mechanical Engineering

11-12—Steam Power Machinery. (For M.E. and Ch.E.) 13-14—Steam Power Machinery (Short M.E. 11-12) (For other than M.E. and Ch.E.)	Phys. 3-4 (General Physics)
15-16—Engineering Thermodynamics	M.E. 13-14
17-18—Engineering Thermodynamics	M.E. 11-12 (Steam Power Machinery)
19-20—Engine Design	M.E. 39-40 (Machine Design) M.E. 17-18 (Eng. Thermodynamics)
21—Gas Power	M.E. 19 (Engine Design) M.E. 17-18 (Engineering Thermo)
23-24—Engineering Thermodynamics	M.E. 13-14
25-26—Steam Power	M.E. 13-14
27-28—Engineering Thermodynamics	M.E. 13-14
29—Engineering Thermodynamics	M.E. 13-14
31-32—Standard Tests and Research Methods *Parallel* M.E. 17-18 (Engineering Thermodynamics)	M.E. 11-12 (Steam Power Machinery)
33—Standard Tests and Research Methods (Continuation of M.E. 31-32)	M.E. 17-18 (Eng. Thermodynamics) M.E. 31-32 Std. Tests and Research Methods
35-36—Kinematics of Machinery	Math. 3-4 (Analytical Geometry)
37—Machine Design	M.E. 59 Empiric Design

Subject	Pre-requisite
38—Kinematics of Machinery	Mach. 3-4
39-40—Machine Design *Parallel* C.E. 53	M. E. 35-36 (Kinematics of Machinery)
41—Machine Design (Short course of M.E. 30-40) *Parallel* C.E. 53 for E.E.	
(For E.E.)	M.E. 35-36 (Kinematics of Machinery)
(For C.E.)	M.E. 78 (Kinematics of Machinery) C.E. 53
45-46—Hydraulic Turbines (For M.E.)	M.E. 36, 60 C.E. 78
(For C.E.)	M.E. 63, 78 C.E. 75
50—Steam Turbines. (For M.E.)	M.E. 17-18 (Eng. Thermodynamics)
52—Organization and Management	M.E. 54 M.E. 94S
53—Steam Turbines. (For E.E.)	M.E. 17-18 (Eng. Thermodynamics)
54—Shop Processes	M.E. 94S (Shop and Factory: Summer Work), Shop work 11
56—Hydraulic Turbine Installations *Parallel* M.E. 60 (Hydraulic Laboratory)	C.E. 77 (Hydraulics)
59—Empiric Design	Draft. 1 or 2 (Elements of Mechanical Drafting)
60—Hydraulic Laboratory. (For E.E.) *Parallel* (For M.E.) C.E. 78. (Hydraulics)	C.E. 77 (Hydraulics)
63—Hydraulic Laboratory *Parallel* C.E. 75 (Hydraulics)	
64—Air Machinery	M.E. 17 (Eng. Thermodynamics)
66—Elevators and Conveyors	M.E. 39 (Machine Design)
70—Pumping Machinery *Parallel* C.E. 78 (Hydraulics)	M.E. 17 (Eng. Thermodynamics)
72—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
74—Gas Power	M.E. 17-18 (Eng. Thermodynamics)
75-76—Standard Tests (For Chem. M.E. 17-18 parallel)	M.E. 13-14 (Steam Power Machinery)
77—Standard Tests. (For C.E. M.E. 17 parallel)	M.E. 13-14 (Steam Power Machinery)
78—Kinematics	Math. 3-4 (Analytical Geometry)
80—Experimental Mechanical Laboratory *Parallel course* M.E. 14	M.E. 13
82—Heating and Ventilation	M.E. 17 (Eng. Thermodynamics)
84-85—Standard Tests	M.E. 13-14 and M.E. 17
86—Standard Tests	M.E. 13-14 and M.E. 17
88—Standard Tests	M.E. 13-14 and M.E. 17
94S—Shop and Factory Summer Work	Sh.Wk. 1 (Wood Turning and Pattern Making) Sh.Wk. 2 (Molding and Foundry Practice) Sh.Wk. 12 (Forging)
96S—Steam Power Plant Summer Work	M. E. 31-32 (Standard Tests, etc.) M.E. 17-18 (Eng. Thermodynamics)
97—Mechanical Apparatus for Chemical Factories	M.E. 11 and 12

Metallurgy

101—General Metallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
111—Metallurgy of Copper	Met. 101 (General Metallurgy)
118—Metallurgy of Copper. (Advanced Course)	Met. 111 (Metallurgy of Copper)
122—Metallurgy of Lead, Silver, Gold and Zinc	Met. 111 (Metallurgy of Copper)
128—Metallurgy of Lead, Silver, Gold, Zinc and the Minor Metals. (Advanced Course)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)

Subject	Pre-requisite
131—Metallurgy of Iron and Steel Prerequisite or *Parallel* Met. 101 (General Metallurgy)	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
134—Metallurgy of Iron and Steel	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
138—Metallurgy of Iron and Steel. (Advanced Course)	Met. 131 (Metallurgy of Iron and Steel)
141—Electrometallurgy	Phys. 3-4 (Elementary Mechanics and General Physics) Chem. 3-4 (General Inorganic Chemistry)
148—Electrometallurgy. (Advanced Course)	Met. 141 (Electrometallurgy)
151—Constitution and Properties of Alloys *Parallel* Met. 131 (Met. of Iron and Steel)	Met. 111 (Metallurgy of Copper)
155-6—Metallography of Iron, Steel and Industrial Alloys	Met. 131 (Met. of Iron and Steel) *or* Met. 134 (Metallurgy of Iron and Steel)
158—Constitution and Properties of Alloys. (Advanced Course)	Met. 151 (Constitution and Properties of Alloys)
72—Metallurgical Laboratory *Parallel* Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)	Met. 111 (Metallurgy of Copper) Met. 131 (Metallurgy of Iron and Steel)
171—Metallurgical Laboratory *Parallel*. Met. 131 (Iron and Steel). Met. 151 (Constitution of Alloys)	Met. 101 (General Metallurgy) and Met. 111 (Metallurgy of Copper)
172—Metallurgical Laboratory	Met. 171 (Metallurgical Laboratory)
173-174—Metallurgical Laboratory	Met. 171 (Metallurgical Laboratory)
175—Metallurgical Investigation *Parallel* Met. 131 (Metallurgy of Iron and Steel, and Met. 141 (Electrometallurgy)	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
77—Met. Plant Construction	Draft. 3-4, 7-8 C.E. 53; Met. 122, 64S and 66S
62S—Summer Course in Non-Ferrous Metallurgy	
64S—Summer Course in Ferrous Metallurgy	Met. 101 (General Metallurgy)
66S—Summer Course in Non-ferrous Metallurgy	Met. 122 (Metallurgy of Lead, Silver, Gold and Zinc)
82S—Summer School in Assaying	Chem. 3-4 and 61-62 Mineralogy 1-2, or 7-8
81—Assaying	Chem. 3-4 and 61-62
182—Assaying	Mineralogy 1-2, or 7-8
188—Assaying	Met. 81 or 182

Mineralogy

1-2—Descriptive and Determinative Mineralogy	Entrance Chemistry Entrance Physics
5—The Minerals of Building Stones	Entrance Chemistry Entrance Physics
6—Optical Mineralogy	Min. 5 (Minerals of Building Stones) *or part of* Min. 1-2 or 7-8 (Descriptive and Determinative Mineralogy) *or equivalent*
7-8—Descriptive and Determinative Mineralogy. (Modification of Min. 1)	Entrance Chemistry Entrance Physics
10—Mineralogy and Crystallography	Min. 15-16
15-16—Determinative Mineralogy	Entrance Chemistry Entrance Physics

Mining

51—Excavation and Tunneling.	Entrance Mathematics Entrance Chemistry Entrance Physics
52—Boring and Shaft Sinking	E.M. 51 (Excavation and Tunneling)

Subject	Pre-requisite
53—Excavation, Tunneling, Boring and Shaft Sinking. (For C.E.) (Condensation of E.M. 51 and 52)	Entrance Mathematics Entrance Chemistry Entrance Physics
54—Exploration, Development, and Methods of Working. (For E.M. and Met.E.) Prerequisite or *Parallel*	Geol. 5-6 Geol. 105-106 (Economic Geology)
56—Mine Engineering Prerequisite or *Parallel*	E.M. 51 and 52 (Excavation and Tunneling, Boring and Shaft Sinking) E.M. 54 E.M. 71-72 (Mine Plant) C.E. 76 (Hydraulics) C.E. 28 (Surveying)
71-72—Mine Plant	E.M. 51-52 E.M. 54 (Exploration, Development and Methods of Working) M.E. 13-14 (Steam Power Machinery)
73—Mine Constructions. (For E.M. and Met.E.)	
75—Design of Mine Plant *Parallel* E.M. 71-72 (Mine Plant)	Draft. 3-4, 7-8 (Structural Drafting) C.E. 53 (Elasticity and Resistance of Materials)
77-78—Graduating Thesis or Project	Mining 59 All required subjects in Mining
80—Mill Constructions	M.E. 13-14 (Steam Power Machinery)
81—Ore Dressing, Milling, and the Mechanical Preparation of Coal. (For E.M. and Met.E.)	Min. 1-2 (Descriptive and Determinative Mineralogy) Phys. 3-4 (Elementary Mechanics and General Physics) Mech. 102 (Analytical Mechanics)
82—Ore-Dressing Laboratory. (For E.M. and Met.E.)	E.M. 81 (Ore Dressing, Milling, and the Mechanical Preparation of Coal)
91—Mine Administration. (For E.M. and Met.E.)	E.M. 54 (Exploration, Development and Methods of Working)
94—Mining Law. (For E.M. and Met.E.)	C.E. 27 (Surveying) E.M. 54 (Exploration, Development and Methods of Working)
58—Summer Class in Mine Surveying	C.E. 27 (Surveying)
59—Summer Course in Practical Mining	M.E. 13-14 (Steam Power Machinery) E.M. 54 (Exploration, Development and Methods of Working) E.M. 51 and 52 C.E. 15 and 27 Geol. 105-106

Physical Education

B1-B2

Physics and Mechanics

Mech. 1—Mechanics: Statics.	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 3-4—General Physics: Mechanics, Wave-motion, Heat and Light	Entrance Physics Entrance Mathematics (including Trigonometry)
Phys. 5—Electricity	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 43-44—Physical Laboratory *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Phys. 55—Physical Measurements *Parallel* Phys. 5	Phys. 3-4 (Mechanics, Wave-Motion, Heat and Light)
Mech. 102—Mechanics	Mech. 1 (Mechanics: Statics) Phys. 3 (Mechanics, Wave-Motion, and first part of Heat) Math. 64 and 65 (Differential and Integral Calculus)
Mech. 105—Thermodynamics	Phys. 4 and Mech. 102 (Mechanics)

Subject	Pre-requisite
Mech. 107-108—Theory of Electricity and Magnetism	Phys. 5 and Math. 64-65
Mech. 109-110—Theory of Alternating Current Machines and Theory of Electrical Circuits	Mech. 107-108 (Theory of Elecricity and Magnetism)

Shop Work

1—Wood-turning and Pattern Making. (For M.E.)	
2—Molding and Foundry Practice. (For M.E.)	
10S—Machine Work. (For M.E.)	Shop Work 10s (Machine Work)
11—Machine Work. (For M.E.)	
12—Forging. (For M.E.)	
13-14—Machine Work. (For E.E.)	
15—Forging and Foundry Practice. (For C.E.)	
16—Machine Work. (For C.E.)	
18S—Pattern-making. (For Chem.E.)	

COURSE IN CHEMICAL ENGINEERING, 1914-1915

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. Chem. 82.	Chem. 41-42.	Phys. 5. Chem. 82.	Chem. 163. E. E. 2. 302 E	Phys. 5. Chem. 82.	Chem. 41-42.
	10—11	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	Chem. 163. E. E. 2.
	11—12	Chem. 81.	Phys. 5. Chem. 164.	Chem. 81.	Phys. 5. Chem. 164.	Chem. 81.	Chem. 163. Chem. 164.
	1—4 Div. A	Chem. 163, Lab. 504 H Mineral. 16. 106 S	Phys. 43, Lab. 410 F Chem. 164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Mineral. 15. 106 S Phys. 44, Lab. 410 F	Chem. 163-164, Lab. 504 H
	1—4 Div. B	Chem. 163, Lab. 504 H Mineral. 16. 106 S	Chem. 163-164, Lab. 504 H	Chem. 163-164, Lab. 504 H	Phys. 43, Lab. 410 F Chem. 164, Lab. 504 H	Mineral. 15. 106 S Phys. 44, Lab. 410 F	Chem. 163-164, Lab. 504 H
	4—5	Phys. Ed. B, Gym., 2 hours a week in sections					
		Shop-work 18s, 3 weeks in June.					
Third Class	9—10	Chem. 101. E. E. 4.	Mech. E. 11-12.	Mech. E. 59. E. E. 4.	Mech. E. 11-12.	Mech. E. 59. Law 2.	Chem. 101. Law 2.
	10—11	Chem. 83-84.	E. E. 73. Div. A. Chem. 102.	Chem. 83-84.	Chem. 49. Chem. 102.	Chem. 83-84.	Chem. 49. E. E. 72. Div. B
	11—12	C. E. 53. Met. 182.	C. E. 53. C. E. 76.	C. E. 53. Met. 182.	C. E. 53. C. E. 76.	C. E. 53. Mech. E. 12.	Mech. E. 11.
	1—4 Div. A	C. E. 53. 301 E C. E. 54, Lab. 308 E	Chem. 49, Lab. 504 H Mech. E. 12. WV	Chem. 49, Lab. 504 H	Chem. 49, Lab. 504 H Met. 182. 601 M	Mech. E. 59. 510 E Met. 182. 601 M	E. E. 73, Lab. 201 E
	1—4 Div. B	C. E. 53. 301 E	Chem. 49, Lab. 504 H C. E. 54, Lab. 308 E	Chem. 49, Lab. 504 H E. E. 72, Lab. 201 E	Chem. 49, Lab. 504 H Met. 182. 601 M	Mech. E. 59. 510 E Met. 182. 601 M	Mech. E. 12, Lab. WV
Fourth Class	9—10	Met. 101, 111. Chem. 122.	Chem. 171.	Met. 101, 111. Chem. 122.	Mech. E. 37. Mech. E. 18.	Met. 101, 111. Chem. 122.	Met. 131.
	10—11	Chem. 197. Mech. E. 97. Chem. 198.	Chem. 197. Mech. E. 97. Mech. E. 76.	Chem. 197. Mech. E. 97. Chem. 198.	Chem. 197. Mech. E. 97. Chem. 184.	Chem. 197. Mech. E. 97. Chem. 198.	Chem. 171. Chem. 184.
	11—12	Chem. 121. Met. 122.	Mech. E. 17.	Chem. 121. Met. 122.	Mech. E. 77.	Chem. 121. Met. 122.	Mech. E. 17. Mech. E. 18.
	1—4	Mech. E. 37. 510 E Chem. 184, Lab. 102 H	Mech. E. 37. 510 E Mech. E. 76. Div. A. Lab. WV Chem. 122. Div. B. Lab. 410 H	Chem. 171, Lab. 504 H Chem. 122. Div. A. Lab. 410 H Mech. E. 76. Div. B. Lab. WV	Mech. E. 77. Div. A. Lab. WV Chem. 171. Div. B. Lab. 504 H Chem. 88, Lab.	Chem. 171. Div. A. Lab. 504 H Mech. E. 77. Div. B. Lab. WV Chem. 88, Lab.	Chem. 88, Lab.

Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *During December and January. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN CHEMISTRY, 1914-1915

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. Chem. 82.	Chem. 41. Chem. 42.	Phys. 5. Chem. 82.	Chem. 163. E. E. 2.	Phys. 5. Chem. 82.	Chem. 41. Chem. 42.
	10—11	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	Chem. 163. E. E. 2.
	11—12	Chem. 81.	Phys. 5. Chem. 164.	Chem. 81.	Phys. 5. Chem. 164.	Chem. 81	Chem. 163. Chem. 164.
	1—4	Phys. 43, Lab. 410 F Mineral. 16. 106 S	Chem. 163, 164, Lab. 504 H	Chem. 163, 164, Lab. 504 H	Chem. 163, 164, Lab. 504 H	Mineral. 15. 106 S Phys. 44, Lab. 410 F	Chem. 163, 164, Lab. 504 H
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	Chem. 101. Chem. 122.	Chem. 171.	Chem. 122.		Chem. 122.	Chem. 101.
	10—11	Chem. 83-84.	Chem. 183. Chem. 102.	Chem. 83-84.	Chem. 102.	Chem. 83-84.	Chem. 171.
	11—12	Chem. 121. Met. 182.	Chem. 175. Mineral. 10.	Chem. 121. Met. 182.	Chem. 175. Mineral. 10.	Chem. 121.	Chem. 183.
	1—4	Chem. 121. 414 H Chem. 88, Lab. 414 H	Chem. 183, Lab. 504 H Mineral. 10. 106 S	Chem. 171, Lab. 504 H Chem. 88, Lab. 414 H	Chem. 171, Lab. 504 H Met. 182, Lab. 601 M	Chem. 175, Lab. 504 H Met. 182, Lab. 601 M	Chem. 175, Lab. 504 H Chem. 88, Lab. 414 H
Fourth Class	9—10	Met. 101, 111.		Met. 101, 111.		Met. 101, 111.	Met. 131.
	10—11		Chem. 141-142.		Chem. 141-142.	Chem. 141-142.	
	11—12	Met. 122.		Met. 122.		Met. 122.	
	1—4		Chem. 89, Lab. 414 H Chem. 43m, Lab. 405 H *b* Thesis				

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *b* Second term only. *First half of term. †For students not having credit in this subject. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. U=University. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN CIVIL ENGINEERING, 1914-1915

	Hours	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10	Min'g 53. Chem. 82.	Mech. E. 13-14.	Phys. 5. Chem. 82.	Mech. E. 13-14.	Min'g 53. Chem. 82.	Bot. 7. Div. A. Mech. E. 13. Div. B. Mech. E. 14. Div. A. Geol. 18. Div. B.
	10—11	Phys. 5. E. E. 2.	Mineral. 5. Geol. 18.	Phys. 5. E. E. 2.	Mineral. 5. Geol. 18.	Phys. 5. Met. 134.	Mech. E. 13. Div. A. Bot. 7. Div. B. Geol. 18. Div. A. Mech. E. 14. Div. B.
	11—12	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	Phys. 5. Met. 134.
	1—2	Dft. 6-8.	Dft. 5. Div. B.		Dft. 5. Div. A.		
	1—4 Div. A	Mineral. 5, Lab. 106 S Dft. 6-8. 601 E	Sh. Wk. 15, Lab. Sec. I, 31 T Phys. 43. Sec. II. 410 F Sh. Wk. 16. Secs. I, II. 125 T Phys. 44. Sec. III. 410 F	Bot. 7. 502 S Phys. 44. Secs. I, II. 410 F Dft. 6-8. Sec. III. 601 E	Dft. 5. 601 E Dft. 6-8. Secs. I, II. 601 E Sh. Wk. 16. Sec. III. 125 T	Phys. 43. Sec. I. 410 F Dft. 6-8. 601 E	Sh. Wk. 15, Lab. Sec. II. 31 T Geol. 18, Lab. and fieldwork
	1—4 Div. B	Mineral. 5, Lab. 106 S Dft. 6-8. 601 E	Dft. 5. 601 E Phys. 44, Lab. Sec. IV. 410 F Dft. 6-8. Secs. V, VI. 601 E	Sh. Wk. 15. Sec. III. 31 T Phys. 43. Sec. IV. 410 F Sh. Wk. 16. Sec. V, VI. 125 T Dft. 6-8. Sec. IV. 601 E	Phys. 43. Sec. III. 410 F Sh. Wk. 15, Lab. Sec. IV. 31 T Phys. 44. Sec. V, V. 410 F Sh. Wk. 16. Sec. IV. 125 T	Bot. 7. 502 S Dft. 6-8. 601 E	Geol. 18, Lab. and fieldwork
	4—5	Phys. Ed. B. 2 hrs. a week in sections.					
Third Class	9—10	C. E. 59. ††E. E. 4. E. E. 72, Lab. Secs. III, IV.	Mech. E. 17. Div. A. Mech. E. 18. Sec. I, III, IV, Mech. E. 78. Secs. II, V, VI.	Mech. E. 17. Div. B. E. E. 4.	C. E. 21. Mech. E. 78.	C. E. 59. E. E. 72.	Mech. E. 17. Div. A. Mech. E. 77. Div. B. Mech. E. 18. Secs. I, III, IV.
	10—11	††C. E. 58. E. E. 72, Lab. Secs. III, IV.	C. E. 51. C. E. 52.	C. E. 58.	C. E. 51. C. E. 52.	C. E. 61. C. E. 58.	Mech. E. 77. Div. A. Mech. E. 17. Div. B. C. E. 52.
	11—12	C. E. 53. ††Mech. E. 18. Sec. II, V, VI. E. E. 72, Lab. Secs. III, IV.	C. E. 53. Mech. E. 78. Secs. I, III, IV. Mech. E. 18. Secs. II, V, VI.	C. E. 53. Ast. 106.	C. E. 53. C. E. 62.	C. E. 53. Mech. E. 78.	C. E. 61. C. E. 62.
	1—4 Div. A	C. E. 53, Lab. 308 E C. E. 54. 402 E. Secs. I, II ††Sec. III	Mech. E. 77, Lab. WV. Secs. I, II C. E. 58. 406 E	Mech. E. 77. Lab. WV Sec. III Ast. 106. 609 F	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53. 301 E E. E. 72, Lab. 201 E. Secs. I, II.—C. E. 54. Sec. III	*C. E. 61. 406 E **C. E. 59, Lab. C. E. 52. 301 E
	1—4 Div. B	C. E. 53. 301 E E. E. 72, Lab. 201 E. Secs. V, VI ††Sec. IV	*C. E. 61. 406 E **C. E. 59, Lab. C. E. 58. 406 E	Mech. E. 77. Lab. WV. Sec. IV Ast. 106. 609 F	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53, Lab. 308 E C. E. 54	Mech. E. 77, Lab. WV. Secs. V, VI C. E. 52. 301 E
Fourth Class	9—10	C. E. 99 C. E. 94.	C. E. 75. C. E. 100	C. E. 99 C. E. 94.	C. E. 75. E. E. 112.	E. E. 75. Law 2.	C. E. 75. Law 2.
	10—11	C. E. 85. C. E. 88.	C. E. 87. Mech. E. 46.	C. E. 85. C. E. 88.	C. E. 87. Mech. E. 46.	C. E. 97 C. E. 90.	Mech. E. 41. Mech. E. 46.
	11—12	C. E. 97. E. E. 112.	C. E. 89.	C. E. 97. C. E. 100	C. E. 89. C. E. 100	E. E. 5. C. E. 90.	C. E. 89. C. E. 90.
	1—4 Div. A	C. E. 100	C. E. 87. 404 E C. E. 100	E. E. 75. 202 E C. E. 88. 404 E	Mech. E. 41. 510 E C. E. 100	C. E. 89. 404 E C. E. 90. 404 E	Mech. E. 63, Lab. WV
	1—4 Div. B	Mech. E. 63, Lab. WV C. E. 100	C. E. 87. 404 E C. E. 100	C. E. 88. 404 E	Mech. E. 41. 510 E C. E. 100	C. E. 89. 404 E C. E. 90. 404 E	E. E. 75

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *Except two afternoons in January. **Two afternoons in January. ††For secs. III, IV, at 1 to 4 P.M., in Rooms 301, 410, 301 E, respectively. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN SANITARY ENGINEERING, 1914-1915

	Hours	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10	Phys. 5. Chem. 82.	Mech. E. 13-14.	Phys. 5. Chem. 82.	Mech. E. 13-14.	Phys. 5. Chem. 82.	Bot. 7. Mech. E. 14.
	10—11	Chem. 65. E. E. 2.	Mineral. 5. Geol. 18.	Phys. 5. E. E. 2.	Mineral. 5. Geol. 18.	Chem. 65. Met. 134.	Mech. E. 13. Geol. 18
	11—12	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	Phys. 5. Met. 134.
	1—2	Dft. 8.	Dft. 5.				
	1—4	Mineral. 5, Lab. 106 S Dft. 8. 601 E	Dft. 5. 601 E Dft. 8. 601 E	Chem. 65, Lab. Sh. Wk. 16. 125 T	Phys. 43. 410 F Phys. 44. 410 F	Bot. 7. 502 S Chem. 76	Chem. 65, Lab. Geol. 18. Lab. and fieldwork
	4—5	Phys. Ed. B. 2 hrs. a week in sections.					
Third Class	9—10	C. E. 59. E. E. 4.	Chem. 41. Chem. 78	E. E. 4.	C. E. 21. Mech. E. 78.	C. E. 59. E. E. 72.	Chem. 41. Chem. 78
	10—11	Chem. 79 C. E. 58.	C. E. 51. C. E. 52.	Chem. 79 C. E. 58.	C. E. 51. C. E. 52.	C. E. 61. C. E. 58.	C. E. 52.
	11—12	C. E. 53.	C. E. 53. Mech. E. 78.	C. E. 53.	C. E. 53. C. E. 62.	C. E. 53. Mech. E. 78.	C. E. 61. C. E. 62.
	1—4	C. E. 53. 308 E C. E. 54. 402 E	Chem. 79 C. E. 58. 406 E	Chem. 79 Chem. 78	C. E. 51. 402 E C. E. 62. 406 E	C. E. 53. 402 E E. E. 72, Lab. 201 E	*C. E. 61. 406 E **C. E. 59, Lab.
Fourth Class	9—10	C. E. 57 a, b. C. E. 94.	C. E. 75. C. E. 100 or Chem. 180	Mech. E. 17. C. E. 94.	C. E. 75.	C. E. 57, a, b. Law 2.	C. E. 75. Law 2.
	10—11	C. E. 85. Mech. E. 82	C. E. 87. C. E. 96.	C. E. 85. Mech. E. 82	C. E. 87. C. E. 96.	C. E. 97. C. E. 90 (Optional)	Mech. E. 17. C. E. 96.
	11—12	C. E. 97. E. E. 76.	C. E. 89. Mech. E. 76.	C. E. 97.	C. E. 89. C. E. 100.	C. E. 90 (Optional)	C. E. 89. C. E. 90 (Optional)
	1—4	Mech. E. 63, Lab. WV E. E. 76. 202 E	C. E. 87. 404 E C. E. 100 or Chem. 180	Chem. 179 Mech. E.. 76. Lab. WV	Chem. 179 C. E. 100 or Chem. 180	C. E. 89. 404 E C. E. 100 or C. E. 90	

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *Except two afternoons in January. **Two afternoons in January. E=Engineering. F=Fayerweather. H=Havermeyer. Hm=Hamilton. K=Kent. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN ELECTRICAL ENGINEERING, 1914-1915

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. Chem. 82.	Mech. E. 13-14.	Phys. 5. Chem. 82.	Mech. E. 13-14.	Phys. 5. Chem. 82.	Phys. 5.
	10—11	Chem. 65. ¶¶Mech. 102.	Mech. E. 13. ¶¶Mech. 102.	Phys. 55. ¶¶Mech. 102.	Phys. 5. ¶¶Mech. 102.	Chem. 65. ¶¶Mech. 102.	Phys. 55,
	11—12	¶Math. 65. E. E. 2.	¶Math. 65. Met. 134.	¶Math. 65. E. E. 2.	¶Math. 65. Met. 134.	¶Math. 65. E. E. 2.	Mech. E. 14.
	1—2				Dft. 5. 402 E		
	1—4 Div. A	Chem. 65, Lab. 504 H Sh. Wk. 14. 125 T	Chem. 65, Lab. 504 H Dft. 6-8. 601 E	Sh. Wk. 13. 125 T Dft. 6-8. 601 E	Dft. 5. 601 E Dft. 6-8. 601 E	Phys. 43. 410 F Phys. 44. 410 F	
	1—4 Div. B	Chem. 65, Lab. 504 H Phys. 44. 410 F	Chem. 65, Lab. 504 H Dft. 6-8. 601 E	Phys. 43. 410 F Dft. 6-8. 601 E	Dft. 5. 601 E Dft. 6-8. 601 E	Shop 13-14. 125 T	
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	E. E. 101. E. E. 104.	Mech. 107. Econ. 2.	E. E. 101. E. E. 104.	Mech. 107. Econ. 2.	Mech. E. 17. E. E. 104.	Mech. E. 41. E. E. 174, Lab. 201 E
	10—11	Mech. E. 17. E. E. 174.	C. E. 77. Econ. 2.	Mech. 105. Mech. 108.	C. E. 77. E. E. 52.	Mech. 105. Mech. 108.	E. E. 101. E. E. 174, Lab. 201 E
	11—12	C. E. 53. Mech. 108.	C. E. 53. E. E. 52.	C. E. 53. Mech. E. 18.	C. E. 53. Mech. E. 76.	C. E. 53. Mech. E. 18.	E. E. 174, Lab. 201 E
	1—4	Mech. E. 41. 510 E Mech. E. 36. 510 E	Mech. E. 76. WV	E. E. 173. Lab. 201 E E. E. 174, Lab. 201 E	E. E. 173, Lab. 201 E Mech. E. 36. 510 E	C. E. 53. 301 E E. E. 52. 502 E	C. E. 53, Lab. 308 E §E. E. 174, Lab. 201 E
Fourth Class	9—10	E. E. 175. 202 E Mech. E. 56.	E. E. 103. E. E. 176.	Mech. E. 53. E. E. 176.	Chem. 183. E. E. 112.	Mech. E. 53. E. E. 176. 202 E	E. E. 105. E. E. 106.
	10—11	E. E. 175. 202 E Mech. 110.	Mech. 109. E. E. 54.	Mech. 109. Mech. 110.	Chem. 183. Mech. E. 72.	E. E. 109. E. E. 176. 202 E	E. E. 105. Mech. E. 72.
	11—12	E. E. 175. 202 E E. E. 112.	E. E. 103. E. E. 106.	Mech. E. 77 Mech. 110.	Chem. 183. E. E. 54.	E. E. 105. E. E. 176. 202 E	E. E. 177. E. E. 110.
	1—2		Mech. 109. 202 Ph				
	1—4	E. E. 175. 202 E *Mech. 110 **§Mech. E. 60. WV	†E. E. 175. ††E. E. 103. E. E. 54. 202 E	E. E. 177. 501 E Phys. 52	Chem. 183. 102 H Mech. E. 72. WV	Mech. E. 77. WV E. E. 176. 202 E	E. E. 177. 501 E *E. E. 108 **§Mech. E. 60. WV

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *First half of term only. **Last half of term only. §As assigned. †2-3 P.M. ††3-4 P.M. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. Ph=Philosophy. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN MECHANICAL ENGINEERING, 1914-1915

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Mech. E. 11. Chem. 82.	Mech. E. 11-12	Mech. E. 59. Chem. 82.	Mech. E. 11-12	Mech. E. 59. Chem. 82.	Phys. 43, Lab. Div. A. 410 F Sh. Wk. 1, Lab. Div. B. 119 T
	10—11	Phys. 5. E. E. 2.	Phys. 5. Met. 134.	Phys. 5. E. E. 2.	Phys. 5 Met. 134.	Phys. 5. Mech. E. 12.	Phys. 44, Lab. Div. A. 410 F Sh. Wk. 12, Lab. Div. B. 29 T
	11—12	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	
	1—2		Dft. 7. Div. B		Dft. 7. Div. A.		
	1—4 Div. A	Sh. Wk. 1, Lab. 119 T Sh. Wk. 12, Lab. 29 T	Sh. Wk. 1, Lab. 119 T Sh. Wk. 12, Lab. 29 T	Mech. E. 35. 506 E Sh. Wk. 2, Lab. 31 T	Dft. 7. 601 E Mech. E. 12, Lab. WV	Mech. E. 59. 510 E Mech. E. 36. 510 E	
	1—4 Div. B	Phys. 43, Lab. 410 F Phys. 44, Lab.	Dft. 7. 601 E Mech. E. 36. 506 E	Mech. E. 35. 506 E Mech. E. 12, Lab. WV	Sh. Wk. 1, Lab. 119 T Sh. Wk. 2, Lab. 31 T	Mech. E. 59. 510 E Sh. Wk. 12, Lab. 29 T	
	4—5	Phys. Ed. B. Gym., 2 hrs. a week in sections					
Third Class	9—10	E. E. 101. E. E. 104.	Mech. E. 39. Mech. E. 32.	Mech. E. 39. E. E. 104.	E. E. 101. Mech. E. 64.	Mech. E. 39. E. E. 104.	Sh. Wk. 11, Lab. Div. A. 125 T Mech. E. 31, Lab. Div. B. WV Mech. E. 66.
	10—11	Mech. E. 31. C. E. 78.	Mech. E. 17. Mech. E. 18.	Mech. 105. C. E. 78.	Mech. E. 17. Mech. E. 64.	Mech. 105. Mech. E. 70.	Sh. Wk. 11, Lab. Div. A. 125 T Mech. E. 31, Lab. Div. B. WV Mech. E. 40. 510 E
	11—12	C. E. 53. Mech. E. 54.	C. E. 53. Mech. E. 70.	C. E. 53. Mech. E. 54.	C. E. 53. Mech. E. 18.	C. E. 53. *Mech. E. 60. §Met. 156.	Sh. Wk. 11, Lab. Div. A. 125 T Mech. E. 31, Lab. Div. B. WV Mech. E. 40. 510 E
	1—4 Div. A	†Sh. Wk. 11, Lab. 125 T *Mech. E. 60, Lab. WV **Met. 156. 508 M	E. E. 73, Lab. 201 E Mech. E. 40. 510 E	Mech. E. 31, Lab. WV Mech. E. 40. 510 E	Mech. E. 39. 510 E C. E. 54, Lab. 308 E	C. E. 53. 301 E Mech. E. 32, Lab. WV	**Met. 156. 508 M
	1—4 Div. B	E. E. 73, Lab. 201 E **Met. 156. 508 M	Sh. Wk. 11, Lab. 125 T Mech. E. 40. 510 E	Mech. E. 39. 510 E Mech. E. 40. 510 E	Sh. Wk. 11, Lab. 125 T Mech. E. 32, Lab. WV	C. E. 53. 301 E C. E. 54, Lab. 308 E	*Mech. E. 60, Lab. WV **Met. 156, 508
Fourth Class	9—10	Mech. E. 19. E. E. 76.	Mech. E. 45. Econ. 2.	Mech. E. 33. Mech. E. 26.	Mech. E. 45. Econ. 2.	Mech. E. 21. Law 2.	Mech. E. 21. Law 2.
	10—11	E. E. 103 A. Mech. E. 50.	E. E. 105 A. Econ. 2.	Mech. E. 19. Mech. E. 26.	Mech. E. 25. Mech. E. 50.	Mech. E. 21. Mech. E. 52.	Mech. E. 21. Mech. E. 52.
	11—12	E. E. 103 A. Mech. E. 50.	E. E. 105 A. Mech. E. 20.	Mech. E. 19.	Mech. E. 25. Mech. E. 20.	Mech. E. 33. Mech. E. 20.	Mech. E. 45. Mech. E. 52.
	1—4 Div. A	Mech. E. 19. 506 E E. E. 76, Lab. 202 E	Mech. E. 21, Lab. WV Mech. E. 26. 506 E	Mech. E. 25. 506 E Mech. E. 20. 506 E	Mech. E. 33, Lab. WV Mech. E. 26. 506 E	Mech. E. 19. 506 E Mech. E. 20. 506 E	
	1—4 Div. B	Mech. E. 19. 506 E Mech. E. 26. 506 E	Mech. E. 33, Lab. WV Mech. E. 26. 506 E	Mech. E. 25. 506 E Mech. E. 20. 506 E	Mech. E. 21, Lab. WV E. E. 76, Lab. 202 E	Mech. E. 19. 506 E Mech. E. 20. 506 E	

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *First half of term. §Second half of term. **Seven afternoons in second half of term. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. K=Kent. M=Mines. S=Schermerhorn. T=Teachers College. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN METALLURGICAL ENGINEERING, 1914-1915

	Hours	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Second Class	9—10	Phys. 5. Chem. 82.	C. E. 23. Chem. 66.	Phys. 5. Chem. 82.	Phys. 5. E. E. 2.	Phys. 5. Chem. 82.	C. E. 23. Chem. 66.
	10—11	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	Phys. 5. E. E. 2.
	11—12	Mineral. 7-8.	Geol. 5-6.	Mineral. 7-8.	Geol. 5-6.	Mineral. 7-8.	Geol. 5-6.
	1—2				Chem. 66.	Dft. 7.	
	1—4	Phys. 43, Lab. 410 F Chem. 66, Lab. 504 H	C. E. 23. 402 E Chem. 66, Lab. 504 H	Mineral. 7, Lab. 106 S Chem. 66, Lab. 504 H	Phys. 43, Lab. 410 F Chem. 66, Lab. 504 H	Dft. 7. 601 E Mineral. 8, Lab. 106 S	
	4—5	Phys. Ed. B, Gym., 2 hrs. a week in sections					
Third Class	9—10	Met. 101, 111. E. E. 4.	Mech. E. 13-14.	Met. 101, 111. E. E. 4.	Mech. E. 13-14.	Met. 101, 111. E. E. 72.	C. E. 64.
	10—11	Met. 81. C. E. 78.	Geol. 105-106.	Mech. E. 13. C. E. 78.	Geol. 105-106.	Met. 81. Mech. E. 14.	Geol. 105-106.
	11—12	C. E. 53. Met. 122.	C. E. 53. Min'g 54.	C. E. 53. Met. 122.	C. E. 53. Min'g 54.	C. E. 53. Met. 122.	Min'g 54.
	1—4	Met. 81, Lab. 601 M Mech. E. 60, Lab. WV	Met. 81, Lab. 601 M	Met. 81, Lab. 601 M E. E. 72, Lab. 201 E	C. E. 53, Lab. 308 E Mineral. 6, Lab. 308 S Geol. 4, Lab. 402 S	C. E. 53. 301 E Mineral 6. Lab. 308 S Geol. 4. Lab. 402 S	C. E. 64
Fourth Class	9—10	Met. 151 Chem. 122.	Min'g 91. Met. 148.	Met. 151. Chem. 122.	Min'g 91.	Met. 175 Chem. 122.	Met. 131. Met. 138.
	10—11	Min'g 81. Min'g 94.	Mech. E. 17. Min'g 94.	Min'g 73. Met. 128.	Met. 141. Mech. E. 72.	Mech. E. 17. Met. 118.	E. E. 75. Mech. E. 72.
	11—12	Chem. 121.	Min'g 81. Mech. E. 76.	Chem. 121. Met. 158.	Min'g 81.	Chem. 121.	Min'g 81. Min'g 80.
	1—4	Met. 171, 77 Mech. E. 76, Lab. WV	Met. 171, 77, Lab. **Min'g 82, Lab. 201 M †Met. 172	Met. 171, 77, Lab. **Min'g 82, Lab. †Met. 172	Met. 171, 77, Lab. **Min'g 82, Lab. 201 M †Met. 172	Met. 171, 77, Lab. **Min'g 82, Lab. 201 M †Met. 172	E. E. 75, Lab. 202 E Mech. E. 72, Lab. WV

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *For students not having credit for this course. **Three weeks consecutive afternoons. †Afternoons not assigned to Mining 82. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. M=Mines. Ph=Philosophy. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only.

COURSE IN MINING ENGINEERING, 1914-1915

	Hours	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Second Class	9—10	Phys. 5. Chem. 82.	C. E. 23. Chem. 66.	Phys. 5. Chem. 82.	Phys. 5. E. E. 2.	Phys. 5. Chem. 82	C. E. 23. Chem. 66.
	10—11	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	¶Math. 65. ¶¶Mech. 102.	Phys. 5 E. E. 2.
	11—12	Mineral. 1-2.	Geol. 5-6.	Mineral. 1-2.	Geol. 5-6	Mineral. 1-2.	Geol. 5-6.
	1—2				Chem. 66.	Dft. 7.	
	1—4	Chem. 66, Lab. 504 H	C. E. 23. 302 E Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	Mineral. 1, Lab. 106 S Chem. 66, Lab. 504 H	Dft. 7. 607 E Mineral. 2. Lab. 106 S	
	4—5	Phys. Ed. B. 2 hrs. a week in sections.					
Third Class	9—10	Min'g 51. E. E. 4.	Mech. E. 13. Mech. E. 14.	Min'g 51. E. E. 4.	Mech. E. 13. Mech. E. 14.	Min'g 51. E. E. 72.	C. E. 64.
	10—11	Met. 81. Div. A. Mech.E. 13. Div. B. Min'g 52.	Geol. 105. Geol. 106.	Mech. E. 13. Div. A. Met. 81. Div. B. Min'g 52.	Geol. 105. Geol. 106.	Met. 81. Mech. E. 80.	Geol. 105. Geol. 106.
	11—12	C. E. 53.	C. E. 53. Min'g 54.	C. E. 53. Mech. E. 14.	C. E. 53. Min'g 54.	C. E. 53.	Min'g 54.
	1—4 Div. A	Met. 81, Lab. 601 M Mech.E. 80, Lab. WV	Met. 81, Lab. 601 M †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Met. 81, Lab. 601 M †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	C. E. 53, Lab. 308 E E. E. 72, Lab.	C. E. 53. 301 E C. E. 54	§C. E. 53, Lab. 308 E C. E. 64, Lab.
	1—4 Div. B	C. E. 53. 301 E C. E. 54	§C. E. 53, Lab. 308 E E. E. 72, Lab. 201 E	C. E. 53, Lab. 308 E Mech. E. 80, Lab. WV	Met. 81, Lab. 601 M †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Met. 81, Lab. 601 M †Mineral. 6, Lab. 308 S ‡Geol. 4, Lab. 402 S	Metal. 81, Lab. 601 M C. E. 64, Lab.
Fourth Class	9—10	Met. 101, 111. Min'g 72.	Min'g 91. Min'g 56.	Met. 101, 111. Min'g 72.	Min'g 91. Min'g 56.	Met. 101, 111. Min'g 72.	Met. 131. Min'g 56.
	10—11	Min'g 81. Min'g 94.	Mech. E. 17. Min'g 94.	Min'g 73. Geol. 110.	Met. 141. Mech. E. 74.	Mech. E. 17. Geol. 110.	E. E. 75. Mech. E. 74.
	11—12	Min'g 71. Met. 122.	Min'g 81. C. E. 76.	Min'g 71. Met. 122.	Min'g 81. C. E. 76.	Min'g 71. Met. 122.	Min'g 81. Min'g 80.
	1—4	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	E. E. 75. Sec. I. 202 E Min'g 75. Sec. II. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. 410 M *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	Min'g 75. Sec. I. 410 M E. E. 75, Lab. Sec. II. 202 E *Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78	*Min'g 82. 201 M **Met. 72. 401 M §§Min'g 78

¶Math. 67, Room 214 Hm, for students not having credit for Math. 64. ¶¶Math. 68, Room 214 Hm, for students not having credit for Math. 65. *Three weeks consecutive afternoons. **Ten consecutive afternoons. †During February and March. ‡During April and May. §As assigned. §§Afternoons not otherwise employed. A=Avery. E=Engineering. F=Fayerweather. H=Havemeyer. Hm=Hamilton. J=Journalism. M=Mines. S=Schermerhorn. U=University. WV=Vault between H and E. Odd numbered courses given in first term only. Even numbered courses given in second term only. Geology 101, Fourth Year Elective, one Aft. per week.

NEW ADVANCED COURSE

NEW ADVANCED COURSE

NEW ADVANCED COURSE

The Trustees of Columbia University, in accordance with the unanimous recommendation of the Faculty of Applied Science, have determined to raise the requirements of admission to the Schools of Mines, of Engineering and of Chemistry, and generally to elevate and strengthen the course of engineering and technical study, from and after July 1, 1914. These schools will then become advanced or graduate schools to which students of any branch of engineering, who have had a suitable preliminary training in scientific school or college, may come for the highest type of professional instruction and for training in methods of research.

After July 1, 1915, candidates for admission to these schools will be required to present evidence of such preliminary general education as can ordinarily be had only by taking at least three years of study in a college or scientific school of high rank. During 1914-15 candidates for engineering degrees will be admitted to the second year of the present course upon presenting evidence that they have completed the work of the present first year in addition to the existing entrance requirements. The Schools of Mines, of Engineering and of Chemistry will, therefore, be placed upon the same academic plane as the present Schools of Law and of Medicine in Columbia University.

The new arrangement need make no substantial change in the age of graduation from the professional school. The student who enters a college at sixteen or sixteen and one-half years of age, and who pursues a combined college and professional school course successfully, can be graduated under the terms of the new plan at about the same age as at present, supposing that he now enters at eighteen and one-half years of age and follows the existing four-year course.

The revised and improved program of studies to be offered in the Schools of Mines, of Engineering and of Chemistry will be strictly professional and specialized for students who are candidates for any one of the several degrees offered in Mines, Engineering and Chemistry. The college or scientific school course, completion of which will be required for admission to these schools, will be one including thorough instruction in Mathematics, Physics and Chemistry, as well as certain designated work in Drafting, Shopwork, Surveying and Mineralogy, together with courses of college grade and type in English, History, Economics, Philosophy and in either French or German.

Beginning in 1915 the schools under the Faculty of Applied Science will offer the following courses:

1. The School of Mines, with three-year advanced courses leading to the degrees of Engineer of Mines and of Metallurgical Engineer.

2. The School of Engineering, with three-year advanced courses in Civil Engineering, Sanitary Engineering, Electrical Engineering, and Mechanical Engineering, leading to the degrees of Civil Engineer, Electrical Engineer, and Mechanical Engineer respectively.

3. The School of Chemistry, with three-year advanced courses, leading to the degrees of Chemist and Chemical Engineer.

The courses are intended to meet the requirements of the several professions indicated; and many of them permit a certain amount of specialization, particularly in the third year. The work in the School of Mines is so arranged that the student can emphasize the engineering, the metallurgical, or the geological side of his profession.

Candidates for a professional degree who have some special end in view are occasionally permitted to vary the regular course by substituting other courses offered under the Faculty of Applied Science.

In the regular Summer Session held at the University in July and August of each year, many courses of assistance to engineering students are offered. The *Announcement of the Summer Session* will be sent upon application to the Secretary of the University.

REQUIREMENTS FOR ADMISSION

Beginning September, 1915, candidates for admission to the new three-year graduate courses in the Schools of Mines, of Engineering and of Chemistry leading to the professional degrees of Engineer of Mines, Metallurgical Engineer, Civil Engineer, Electrical Engineer, Mechanical Engineer, Chemical Engineer and Chemist, must present evidence of the satisfactory completion of not less than three years of study or the equivalent in an approved college or scientific school, which course must have included sufficient instruction in chemistry, mathematics and physics to enable the candidate to undertake the work of the engineering courses. The candidate must also present evidence of having had the first courses in Drafting, Mineralogy, Shopwork and Surveying.

Graduates of colleges and technical schools may be admitted to advanced standing by submitting evidence that they have satisfactorily completed courses required in the class or classes preceding the one for which application for admission is made.

Students at other colleges who contemplate entering the Schools of Mines, of Engineering and of Chemistry are advised to apply to the Secretary of Columbia University for advice as to how best to select and arrange their courses of study with a view to the proper articulation between them and the professional work at Columbia upon which they expect to enter later.

For students who take their preliminary college or scientific course elsewhere than at Columbia, opportunity will be offered in the Summer Session of Columbia University during July and August to receive

instruction in any of the subjects required for admission and for which provision may not be made in the college which they attend.

Students who have been looking forward to entering Columbia University for the study of Mining, of any branch of Engineering or of Chemistry, and who expected to enter upon the terms of admission heretofore prevailing, need make no change in their plans.

They will be received at Columbia just as at present, but they will be differently classified. On completing the subjects required for admission to the Schools of Mines, of Engineering and of Chemistry as newly established, they will be transferred to the school of their choice.

For full particulars, address the Secretary of Columbia University.

MINING ENGINEERING

General Statement

The three-year course leading to the degree of Engineer of Mines is intended primarily to train men to undertake the development of mineral properties, the design and construction of mine plants, and to manage mines.

The subjects most emphasized in this course are mining, metallurgy, geology and engineering.

The proper design and construction of mining plants involves the study of certain branches of civil engineering and the many and increasing applications of machinery to mining make it necessary to give much time to the theory and practice of mechanical and electrical engineering.

The engineering, mining and metallurgical laboratories are equipped to train the student in the making of scientific tests of engineering materials, and working tests of machines and processes of ore treatment, thus preparing him, as far as it is possible in the school, for work that he will be called upon to do as an engineer.

Practical instruction in summer classes in the field is made an important feature of the curriculum.

While much time is given to practical training in laboratories, in the field, and at the mines and metallurgical establishments, care is taken to subordinate this instruction to a high standard of accomplishment in classroom work.

Location. Many coal, iron and other mines, together with quarries and metallurgical works, are easily accessible from New York in from one to four hours by rail. Among these are magnetic iron mines in New York, New Jersey and Pennsylvania; stone quarries in the same States and in Connecticut; anthracite and bituminous coal mines, and natural gas and oil wells in Pennsylvania, and zinc mines in New Jersey. New York and the adjacent States produce each year about half the pig-iron and coal, and over fifty per cent. of the total value of the mineral product of the whole country. There are within easy reach of New York City iron blast furnaces and some of the most skilfully designed and managed steel works, rolling mills, steel and iron foundries, copper smelting and refining works, lead-refining works, zinc works, and electrolytic establishments in the world. Within a radius

of one hundred miles may be studied many phases of the best practice in mining and metallurgy in the country. By going a little farther one may reach the bituminous coal fields and the natural gas, oil and salt regions in one direction, and the pyrite deposits, and granite and marble quarries of New York and New England in the other; while the excursions of the summer class in mining extend as far as the copper, iron, zinc, lead, silver and gold regions of Michigan, Missouri, Montana, Colorado, California, Arizona and Utah.

COURSES IN MINING ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Quantitative Analysis	2	4
Mechanics	3	0	Mechanics	3	0
Industrial Chemistry	3	0	Industrial Chemistry	3	0
Elements of Electrical Engr.	2	0	Electrical Machinery	2	0
Power Machinery	2	1	Power Machinery	2	0
General Geology	3	1	General Geology	3	0
Mineralogy	4	2	Railroad Surveying Theory	2	1
Total	17	5	Total	17	5

SUMMER WORK

Topographic and Mine Claim Surveying 5 weeks
Railroad Surveying, Field Work 3 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Resistance of Materials	5	2	Graphic Statics	1	1
Assaying	2	3	Electrical Distribution	2	0
Economic Geology	3	0	Direct Current Laborat'y	1	1
Engineering Thermo-dynamics	2	0	Economic Geology	3	0
Excavation and Tunneling	3	0	Engineering Thermo dynamics	2	0
Mine Constructions	1	0	Mechanical Laboratory	1	1
Sanitation and Hygiene	2	0	Petrography and Optical Mineralogy	0	2
			Boring and Shaft Sinking	2	0
			Methods of Mining	3	0
			Mill Constructions	1	0
			Elementary Metallurgy	1	0
Total	18	5	Total	17	5

SUMMER WORK

Mining Practice, 6 weeks; Mine Surveying, 1 week; Field Metallurgy, 1 week; Field Geology, 1 week.

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Alternating Current Laboratory	1	1	Hydraulic Laboratory	0	1
Introduction to Metallurgy and Metallurgy of Copper	3	0	Gas Power	2	0
Electrometallurgy and Iron and Steel	2	0	Geological Surveys	2	0
Hydraulics	2	0	Metallurgy of Gold, Silver etc.	3	0
Mine Plant	3	0	Metallurgical Laboratory	0	½
Design of Mine Plant	0	4	Mine Administration and Accounts	2	0
Ore Dressing	4	0	Mine Engineering	3	0
Steam Power Machinery	3	0	Mine Plant	3	0
			Mining Thesis	0	2⅔
			Ore Dressing Laboratory	0	1
			Mining Law	2	0
Total	18	5	Total	17	5⅙
Petrography (Elective)	2	1	Palæontology (Elective)	2	1

METALLURGICAL ENGINEERING

General Statement

The primary aim of the three-year course leading to the degree of Metallurgical Engineer is to train students to take laboratory or administrative positions in metallurgical works. Great stress is laid on the original planning and executing of work, under constant criticism and discussion from the teachers.

The instruction consists of (1) classroom work, lectures, conferences, study of text books; (2) general laboratory work in metallurgy; (3) training in planning and executing original research; (4) summer courses and other visits to industrial metallurgical works.

Much importance is attached to a thorough training in chemistry, physics, geology, mineralogy and engineering, and to the higher branches of engineering, chemistry and important courses in mining engineering, with a view to their applications to metallurgical and like manufacture.

The instruction in metallurgy is based on the most advanced practice in science of to-day and covers the ground from the introductory courses in metallurgy to the special advanced courses in the various branches of the subject.

COURSES IN METALLURGICAL ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Electrical Machinery	2	0
Mechanics	3	0	Mechanics	3	0
Industrial Chemistry	3	0	Industrial Chemistry	3	0
Elements of Elect. Eng.	2	0	Railroad Surveying Theory	2	1
Power Machinery	2	1	Power Machinery	2	0
General Geology	3	1	General Geology	3	0
Mineralogy	4	2	Quantitative Analysis	2	4
Total	17	5	Total	17	5

SUMMER WORK

Topographic and Mine Claim Surveying	5 weeks
Railroad Surveying, Field Work	3 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Resistance of Materials	5	2	Graphic Statics	1	1
Assaying	2	3	Direct Current Laboratory	1	1
Economic Geology	3	0	Economic Geology	3	0
Engineering Thermodynamics	2	0	Engineering Thermodynamics	2	0
Introduction to Metallurgy	1	0	Metallurgy of Lead, Silver, Gold and Zinc	3	0
Metallurgy of Iron and Steel	1	0	Electrical Distribution	2	0
Metallurgy of Copper	2	0	Mechanical Laboratory	1	1
Sanitation and Hygiene	2	0	Methods of Mining	3	0
			Petrography and Optical Mineralogy	0	2
			Business Law	2	0
Total	18	5	Total	18	5

SUMMER WORK

Metallurgy—Visits to Non-ferrous Works	3 weeks
Metallurgy—Visits to Iron and Steel Works	3 weeks
Geology Field Work	1 week
Reports on Field Work	1 week

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Chemistry	3	0	Mine Administration and Accounts	2	0
Alternating Current Laboratory	1	1	Gas Engines and Producers	2	1
Steam Power Machinery	3	0	Advanced Metallurgical Courses	5	0
Electrometallurgy	1	0	Metallurgical Laboratory	0	1
Constitution of Alloys	2	0	Mill Construction	1	0
Metallurgical Laboratory	0	4	Ore Dressing	0	1
Mine Construction	1	0	Mining Law	2	0
Ore Dressing	4	0	Hydraulic Laboratory	0	1
Hydraulics	2	0	Metallurgical Conferences and Plant Design	1	1
Total	17	5	Total	13	5

CIVIL ENGINEERING

General Statement

The three-year course leading to the degree of Civil Engineer is designed to afford a thorough analytical training in construction and management. The course contains numerous and extended practical exercises in those matters which pertain to the profession of the civil engineer in relation to all classes of structures and public works and in connection with the various developments and applications of power by the use of steam, electric, water, and air motors. This course is also designed to be an educational preparation for those duties or functions of an executive character whose discharge in connection with the management of public or other works requires, or is rendered more efficient through, a thorough knowledge of civil engineering. The breadth and nature of this educational training adapts it no less efficiently to the purposes of those who intend to follow callings not of an engineering character, but which may be related more or less to manufacturing, to structural matters, or to the development and application of power. The theoretical portion of the instruction is based largely upon the courses given in the departments of Mathematics, Mechanics and Physics, and the results obtained are applied to practical engineering work. Special stress is laid upon the design by the student of the various structures and machines which the civil engineer is called upon to construct or operate in the practice of his profession. The instruction is given by lectures, demonstrations by the student, and frequent conferences, co-ordinate with which the work of design is continuously carried on. It covers comprehensively the subjects of surveying, road and railroad engineering, water supplies of cities and towns, irrigation, sewage disposal, both graphic and analytic treatment of all metallic structures, foundations, retaining and reservoir walls, high masonry dams, sewer systems, hydraulic engineering, rivers and harbors, pumping engines, hydraulic, steam and electric motors.

Ample facilities are afforded for post-graduate students in civil engineering, and special students are admitted to various engineering courses of the department upon evidence of proper qualifications.

COURSES IN CIVIL ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Advanced Heat	3	0
Mechanics	3	0	Mechanics	3	0
Industrial Chemistry	3	0	Industrial Chemistry	3	0
Power Machinery	2	1	Power Machinery	2	0
Elements of Electrical Engr.	2	0	Electrical Machinery	2	0
Geodesy	2	0	Geodesy	1	1
Eng. Chemistry	1	2	Botany—Timber Growth	1	1
General Geology	3	1	Physiographic and Applied Geology	2	1
Metallurgy—Iron and Steel	2	0	Highway Engr. and Earthwork Calculation	1	1
Total	18	5	Total	18	4

SUMMER WORK

Topographic Surveying, Highway Surveying, City Surveying, Hydrographic Surveying — 5 weeks

Geodetic Surveying — 5 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Railroad Surveying	2	1	Railroad Surveying	3	1
Resistance of Materials (Theory, Designs and Tests)	5	2	Masonry Structures	3	2
Theory of Trusses	2	1	Sanitary Treatment Water Supply and Sewerage	3	0
Engineering Thermodynamics	2	0	Graphic Statics	2	1
Kinematics and Machine Design	3	1	Engineering Thermodynamics	2	0
Excavation, Tunneling, Boring and Shaft Sinking	2	0	Direct Current Laboratory	1	1
			Hydraulics	4	0
Total	16	5	Total	18	5

SUMMER WORK

Railroad Surveying 4 weeks

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Foundations	2	0	Business Law	2	0
Bridges, Roofs and Buildings	2	2	Bridges, Roofs and Buildings	2	0
Concrete Steel Construction	2	0	Alternating Current Laboratory	1	1
Railroad Engineering	3	1	Railroad Engineering	3	1
Electrical Distribution	2	0	Electric Railways	2	0
Water Supply and Irrigation	2	0	Design and Construction of Sewers, River and Harbor Improvements	2	0
Hydraulic Laboratory	0	1	Hydraulic Turbines	3	0
Mechanical Laboratory	1	1	Thesis	2	3
Thesis	3	0			
Total	17	5	Total	17	5

SANITARY ENGINEERING

General Statement

The three-year graduate course in Sanitary Engineering aims to include the more essential subjects given in the Civil Engineering course, but provides a working knowledge of sanitary science and the sanitary arts. The course is a differentiation of Civil Engineering and leads to the same degree.

While mathematics, mechanics and physics are the theoretical basis for the work of the civil engineer in design, construction and management, the sanitary engineer adds to these the collateral sciences of chemistry and biology.

The sanitary engineer must not only be able to design and construct water purification plants and sewage disposal systems, but he must understand the chemical and biological processes upon which the successful operation of these plants is based. He must not only be able to construct such engineering features as will prevent epidemics and further the health and comfort of individuals and communities, but he must have a knowledge of bacteriology, sanitary statistics and the sources and modes of infection.

Instruction is given by illustrated lectures, conferences and demonstrations supplemented by field and laboratory practice. The field work includes instruction in the use of transits, levels and plane tables, current meters, gauges and floats, and visits of inspection. The laboratory work in hydraulics consists of the measuring of wier and orifice discharge, the flow through open channels and closed pipes and general hydraulic investigations.

The mechanical laboratories are provided with means for testing various structural materials in tension, compression, bending and torsion. There are also special laboratories for cement testing and for testing road materials.

The sanitary laboratories have a full equipment for the chemical, microscopical and bacteriological examination of water and sewage and for sanitary chemical and biological investigations.

COURSES IN SANITARY ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Advanced Heat	3	0
Mechanics	3	0	Mechanics	3	0
Industrial Chemistry	3	0	Industrial Chemistry	3	0
Power Machinery	2	1	Power Machinery	2	0
Elements of Electrical Engineering	2	0	Electrical Machinery	2	0
Quantitative Analysis	2	2	Quantitative Analysis and Engr. Chemistry	2	3
General Geology	3	1	Physiographic and Applied Geology	2	1
Metallurgy of Iron and Steel	2	0	Botany—Timber Growth	1	1
Total	17	5	Total	18	5

SUMMER WORK

Topographic Surveying, Highway Surveying, City Surveying — 5 weeks
Hydrographic Surveying — 2½ weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Railroad Engineering	2	1	Direct Current Laboratory	1	1
Resistance of Materials	5	1	Masonry Structures	3	2
Theory of Trusses	2	1	Graphic Statics	2	1
Engineering Thermodynamics	2	0	Engineering Thermodynamics	2	0
Sanitary Biology and Sanitary Bacteriology	3	1	Sanitary Treatment Water Supply and Sewerage	3	0
Organic Chemistry	3	1	Organic Chemistry	3	1
			Hydraulics	4	0
Total	17	5	Total	18	5

SUMMER WORK

Railroad Surveying 4 weeks

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Foundations	2	0	Heating and Ventilation	2	0
Bridges, Roofs and Buildings	2	2	Bridges, Roofs and Buildings	2	0
Concrete Steel Construct'n	2	0	Alternating Current Laboratory	1	1
Mechanical Laboratory	1	1	Hydraulic Laboratory	0	1
Electrical Distribution	2	0	Hydraulic Turbines	3	0
Phys. and Biological Water Analysis	0	2	Principles of Sanitary Science, Public Health and Hygiene	3	0
Statistics and Interpretation of Water Analysis	3	0	Design and Construction of Sewers, River and Harbor Improvements	2	0
Drainage of Marshes and Lowlands / Water Sup. & Irrigation	2	0	Business Law	2	0
Thesis	3	0	Thesis	2	2
			Highway Eng. and Earthwork Calculation	1	1
Total	17	5	Total	18	5

ELECTRICAL ENGINEERING

General Statement

The course leading to the degree of Electrical Engineer is designed for the education of those who intend to practice the profession of Electrical Engineering either as engineers, managers, experts in industrial or public service enterprises, teachers in colleges or technical schools or for those who expect to be interested in a financial or commercial way with these enterprises.

The instruction comprises the important branches of theoretical and applied electricity, also the fundamental and collateral subjects, which have been found by experience to be required by the electrical engineer, as, for example, physics, chemistry, drawing, mechanical engineering (including boilers, gas producers, engines, turbines, transmission devices and shop work), civil engineering (including hydraulic developments and construction in wood, masonry, iron and steel).

The graduate in Electrical Engineering is accordingly provided not only with a thorough knowledge of the principles and applications of electricity, but also with such a broad and liberal education in the allied sciences as will prepare him for the demands likely to be made upon him in connection with the practice of his profession.

The instruction is by lectures and recitations as well as by a large amount of carefully selected and supervised laboratory work, work shop and drawing room practice with periodic visits to the numerous and important factories, power stations and other engineering establishments in and about New York City. Facilities are also provided for original research work at the option of the student.

COURSES IN ELECTRICAL ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	1	0	Electrical Machinery	2	0
Mechanics	0	3	Mechanics	3	0
Industrial Chemistry	0	3	Industrial Chemistry	3	0
Power Machinery	1	2	Power Machinery	2	1
Elements of Electrical Eng.	0	2	Advanced Heat	3	0
Metallurgy of Iron and Steel	0	2	Business Law	2	0
Machine Elements	0	2	Physics	2	1
General Geology	0	3	Machine Elements	0	2
Engineering Chemistry	2	1			
Total	4	18	Total	17	4

SUMMER WORK
Description of a D.C. Power Plant
or Employment in Elect. Engr. work for 8 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Direct Current Engr.	3	0	Design of Direct Current Machinery	3	1
Direct Current Laboratory	3	2	Direct Current Laboratory	2	1
Theory of Elect. and Magnetism	2	0	Telegraphy and Telephony	2	0
Resistance of Materials	5	1	Theory of Elect. and Magnetism	3	0
Engineering Thermodynamics	2	0	Electro Chemistry	2	1
Hydraulics	2	0	Electrical Distribution	3	0
Mechanical Laboratory	1	1	Engineering Thermodynamics	2	0
			Hydraulic Laboratory	0	1
			Mechanical Laboratory	1	1
Total	18	4	Total	18	5

SUMMER WORK
Description of an A.C. Power Plant
or Employment in Elect. Engr. work for 8 weeks

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Theory of the Electric Circuit	4	0	Theory of the Electric Circuit	2	0
Alternating Current Engineering	3	0	Electric Plants	2	0
Alternating Current Laboratory	2	3	Design of A. C. Machinery	3	1
Application of Electric Machinery	3	0	Electric Railways	2	0
Standardizing Laboratory	1	1	Alternating Current Laboratory	2	3
Theory of Dielectrics	1	0	Illumination & Photometry	1	1
Steam Turbines	2	0	Steam Power Machinery	3	0
Gas Power	2	1	Hydraulic Turbines	3	0
Total	18	5	Total	18	5

MECHANICAL ENGINEERING

General Statement

The three-year graduate course in Mechanical Engineering offers a thorough basic training in the design, construction, manufacture and operation of all classes of standard and special machinery for manufacturing, mining, metallurgical, electrical and chemical processes, and their economic application to rallroads, ships, mills, shops, factories and power plants.

While it deals most thoroughly with the scientific and technical problems arising in engineering practice, it also provides for instruction in the organization of commercial and industrial enterprises, the management and control of properties, the economic use of materials, machinery and the labors of men, and in the laws which condition the existence and prosperity of industrial institutions. Through experimental investigations and analysis, in laboratories, drafting rooms and shops and the systematic presentation of subject matter in the classroom, an attempt is made to familiarize the student with standard practice in mechanical engineering service; the reasons for their existence, and to develop habits of initiative and independent thinking.

The course of instruction is as broad and fundamental as is consistent with the directness of its purpose and the immediate usefulness of its graduates.

COURSES IN MECHANICAL ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Advanced Heat	3	0
Mechanics	3	0	Mechanics	3	0
Industrial Chemistry	3	0	Industrial Chemistry	3	0
Metallurgy of Iron and Steel	2	0	Electrical Machinery	2	0
Elements of Elect. Engr.	2	0	Power Machinery	2	0
Power Machinery	2	1	Machine Elements	2	1
Machine Elements	2	0	Shop Processes	3	2
Shop Processes	1	0	Hydraulic Laboratory	0	1
Hydraulics	2	0	Metallurgical Laboratory	0	1
Mech. Instrument Lab.	0	1			
Engineering Chemistry	1	2			
Total	18	5	Total	18	5

SUMMER WORK

Departmental Shops	5 weeks
Manufacturing Shop; Inspection and Report	3 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Resistance of Materials	5	1	Electrical Distribution	2	0
Direct Current Machinery	2	0	Direct Current Laboratory	1	1
Engineering Thermodynamics	3	1	Machine Tools	2	0
Mechanics of Machinery	5	2	Air Machinery	2	0
Pumping Machinery	2	0	Engineering Thermodynamics	5	1
Air Laboratory	1	1	Design of Machine Elements	5	2
Total	18	5	Steam Laboratory	1	1
			Total	18	5

SUMMER WORK

Departmental Machine Design and Detailing	5 weeks
Central Station or Factory Power Plant; Inspection and Report	3 weeks

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Alternating Current Machinery	3	0	Alternating Current Laboratory	1	1
Steam Turbines	2	1	Hydraulic Turbines	3	1
Piston Steam Engines	2	1	Gas Engines & Producers	4	0
Heat Transfer Apparatus	3	0	Steam Power Plants	4	2
Industrial Building Design	2	1	Organization and Management	3	0
Mill and Factory Equipment	5	1	Business Law	2	0
Steam Laboratory	1	1	Gas Engine Laboratory	1	1
Total	18	5	Total	18	5

CHEMICAL ENGINEERING

General Statement

The courses of instruction leading to the degree in Chemical Engineering are carefully chosen with a view to training men to develop and direct those industrial and manufacturing operations and processes which are based upon the application of chemistry. A general knowledge of Civil Engineering is obtained from courses in the theory and the practise of Surveying, Hydraulics and Resistance of Materials. Electrical applications are studied in the Direct and Alternating Current Laboratories with the electrical engineers. A study of steam and gas power machinery, pumps, turbines, blowers and hydraulic equipment in the mechanical engineering laboratories supplements the courses in general physics, thermodynamics and hydraulics.

In addition to the training in the fundamental engineering courses, it is sought to advance the students' knowledge of chemistry into the fields of physical chemistry, organic chemistry, advanced inorganic chemistry and the more important special applications of industrial chemistry.

During the final year much attention is given to the development of the skill of the student in the application of the fundamental, engineering and chemical principles studied earlier in the course to the practical problems of the industry. The Chemical Engineering Laboratory is so equipped and managed as to develop the power of making direct application of previous training.

Graduates in Chemical Engineering obtain positions in works laboratories as assistants to superintendents of works, and assistants to designing and erecting chemical engineers, and in various other capacities calculated to develop the experience leading to the independent direction and management of manufacturing enterprises.

COURSES IN CHEMICAL ENGINEERING

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Advanced Heat	3	0
Mechanics	3	0	Mechanics	3	0
Industrial Chemistry	3	0	Industrial Chemistry	3	0
Power Machinery	2	0	Power Machinery	2	0
Physical Chemistry	3	1	Physical Chemistry	3	1
Elements of Electrical Engr.	2	0	Electrical Machinery	2	0
Hydraulics—Theory	2	0	Hydraulics—Laboratory	0	1
Quantitative Analysis	2	3	Quantitative and Engr. Chemistry	2	3
Total	17	5	Total	18	5

SUMMER WORK

Chemical Factory Inspection 2 weeks
Chemical Factory Work and Report 6 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Organic Chemistry	3	2	Organic Chemistry	3	2
Machine Elements	2	0	Machine Elements	2	0
Sanitary and Food Chemistry	3	0	Advanced Industrial Chemistry	3	0
Engineering Thermodynamics	3	0	Engineering Thermodynamics	5	0
Direct Current Laboratory	1	1	Alternating Current Laboratory	1	1
Resistance of Materials	5	2	Assaying	2	2
			Electrical Distribution	2	0
Total	17	5	Total	18	5

SUMMER WORK

Chemical and Mechanical Engineering Laboratory 6 weeks

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Introduction to Metallurgy and Metallurgy of Copper	3	0	Metallurgy of Lead, Zinc, Gold and Silver	3	0
Metallurgy of Iron and Steel	1	0	Chemical Factory Management	3	0
Chemical Factory Machinery	3	0	Steam Power	4	2
Electro-Chemistry	2	1	Business Law	2	0
Gas Power	2	1	Chem. Engr. Lab.—Special Problems	0	3
Commercial Organic Analysis	2	3	Seminar	6	0
Seminar	5	0			
Total	18	5	Total	18	5

CHEMISTRY

General Statement

The graduate years include courses in all branches of Chemistry. In view of the increasing use of electricity in Industrial Chemistry, this science is studied continuously during the first two years. In the third year the work is all elective, and it is concentrated in two subjects each half year, to the end that the student may devote himself to two or more branches of the science, and develop to the fullest extent his knowledge of the lines of work chosen. Throughout the three years, by means of preceptorial conferences, much attention is given to outside reading and to practising the art of mastering all that is known about a given topic. The chemical courses furnish the student with technical knowledge of the methods of the science. The conferences enable him to recognize, to lay out, and to solve the problems which his professional work will constantly bring to him for solution.

The three-year course in Chemistry prepares men for professional careers as analytical and consulting chemists, teachers of chemistry, research workers in the government, State, municipal and endowed scientific laboratories, and as chemists for the operating departments of railroads and of large industrial establishments which maintain separate chemical and engineering staffs, such as packing houses, sugar refineries, and other large food factories, fertilizer works, gas works, textile and dye works, and establishments where glass and ceramic products, explosives, illuminating and lubricating oils, metals and alloys, alkalies, acids, drugs, and innumerable other products are manufactured.

Problems arising in factories and in public and private undertakings, which do not constantly employ chemists, and special problems arising in factories which do employ chemists, are constantly referred to analytical and consulting chemists.

The agricultural experiment stations, the Federal and State food laboratories, the boards of health, the State and national geological surveys, and the many privately endowed institutions for scientific research, employ very large numbers of chemists as workers and directors.

Many of the larger and more progressive manufacturing establishments maintain thoroughly equipped laboratories devoted entirely to experimental research for the purpose of improving present manufacturing processes and for devising new and better ones.

THE GREEN AND UNION THEOLOGICAL SEMINARY FROM QUADRANGLE

COURSES IN CHEMISTRY

FIRST YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Laboratory	0	1	Industrial Chemistry	3	0
Industrial Chemistry	3	0	Elements of Electrical Machinery	2	0
Elements of Electrical Engr.	2	0	Quantitative Analysis	2	3
Quantitative Analysis	2	3	Organic Chemistry	3	2
Organic Chemistry	3	2	Conferences	6	0
Conferences	3	0			
Total	13	6	Total	16	5

SUMMER WORK

Bacteriology (Microbiology) 6 weeks
Chemical Factory Inspection 2 weeks

SECOND YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
Physical Chemistry	3	1	Physical Chemistry	3	1*
Sanitary and Food Chemistry	3	0	Food Analysis	2	2
Electro-Chemistry	2	1	Advanced Industrial Chemistry	3	0
Mineralogy (9)	2	1	Metallography		1*
Geology	3	1	Mineralogy (10)	2	1
Direct Current Laboratory	1	1	Alternating Current Laboratory	1	1
Conferences	4	0	Conferences	4	0
Total	18	5	Total	15	6

*Concentrated into 2 weeks.

SUMMER WORK

Commercial Organic Analysis 6 weeks

THIRD YEAR

First Half			*Second Half*		
Subjects	Hours	Aft.	Subjects	Hours	Aft.
*1st Elective	3	4	*3d Elective	3	4
*2d Elective	3	4	*4th Elective	3	4
Total	6	8	Total	6	8

*These four electives are to be chosen from the following courses:

Experimental Physical Chemistry.
Experimental Inorganic Chemistry.
Advanced Organic Chemistry.
Advanced Food Chemistry.
Experimental Electro-Chemistry.
Advanced Analytical Chemistry.

GENERAL INFORMATION

REGARDING COLUMBIA UNIVERSITY

Columbia University was founded in 1754 as King's College. In 1784, after the Revolutionary War, King's College became, by act of the Legislature of the State of New York, Columbia College. The institution whose name was thus changed has become Columbia University.

Students in the Schools of Mines, Engineering and Chemistry may enjoy every advantage to be derived from the resources of the University. The University occupies thirty-six buildings, and its grounds cover thirty-five acres. The number of officers of instruction in 1913-14 was 849, and of resident students 9,929.

University Library The Library contains more than 500,000 bound volumes, catalogued both by authors and by subjects.

It is open each week-day from 8.30 A.M. until 11 P.M. (in summer, 10 P.M.). All students and graduates have free access and may draw books for home use.

Physical Exercise The Gymnasium is open each week-day from 9 A.M. to 7 P.M.; and on Mondays, Thursdays, and Saturdays until 10 P.M.

Every student is entitled to a physical examination by the Medical Director and to advice as to the kind and amount of exercise best adapted to his needs. For the Gymnasium see Fees, page 21.

The main exercising room is 35 feet high, semicircular in shape, and has an area of 16,000 square feet. It is well lighted and well ventilated. Above are the 10-lap running track, rooms for fencing, boxing, and handball, dressing-rooms with 1,804 steel lockers, and 32 shower-baths. Below the exercising room is the semicircular swimming pool, 100 feet by 50, and 4 to 10 feet deep, and shower-, needle-, and tub-baths.

A two-hour course in Physical Education is prescribed for all first and second year undergraduate students, arranged with a view to securing: first, health; second, strength, control, efficiency, and endurance; third, erect carriage.

There are on South Field a practice field for baseball, lacrosse, and football, a quarter mile running track, tennis courts, and the University Boat House is within easy reach.

Employment Committee The Employment Committee endeavors to give students who need it the opportunity to earn enough for partial or complete support, and to extend assistance in other ways. The office of the secretary of the Committee is in

Room 327, University Hall. Communications should be addressed to the Committee. Some of the openings available are: private tutoring, translating, addressing, copying of various sorts, teaching in evening schools, stenography. During the last ten years student earnings reported to the Committee have averaged about $100,000.00.

Preference is naturally given, in case of a choice of applicants, to those who, as strangers in New York, are not likely to hear of positions through other channels. No prospective student should come to Columbia expecting to depend entirely or even largely upon the assistance of the Committee, and every student should be prepared to meet at least the expenses of the first half-year—say $250.

The chiefs of clinic in the Medical School give advice without charge to students on the lists of the Committee.

There are also Appointment Committees whose duty it is to recommend graduates for teaching or other positions in colleges and universities and to assist competent men to obtain such positions.

Medical Attendance

The University Medical Officer, Dr. McCastline, will have direct supervision of all matters affecting the health of the student body. All cases of communicable disease occurring in homes of students must be promptly reported to him.

As University physician Dr. McCastline will hold office hours daily in Earl Hall for consultation with the students.

For those who are without local family physicians there is a Medical Visitor (Dr. D. S. D. Jessup, 601 W. 113th Street) whose duties are to render medical assistance to such officers and students as may desire it, either at their homes or elsewhere, at a remuneration to be arranged between himself and individual patients.

Residence Halls

There are three University residence halls on South Field, with accommodations for 700 men; Hartley Hall, a memorial to the late Marcellus Hartley, Livingston Hall, named in memory of Robert R. Livingston, of the class of 1765, and Furnald Hall, provided for in the will of the late Francis P. Furnald in memory of his son, Royal Blackler Furnald, a member of the class of 1901. Each building is 137 feet by 60 and 10 stories high. They have electric light, steam heat, telephones, elevators and shower baths.

Hartley and Livingston each contain 300 rooms, the average size of the bedrooms being 8′ 0″ x 14′ 6″, and of the studies 10′ 0″ x 14′ 6″. Furnald contains 294 rooms, the average size of the bedrooms being 9′ 0″ x 14′ 9″, and of the studies 11′ 6″ x 13′ 6″. All the rooms have outside light and exposure, and the arrangement permits of flexibility in rent-

ing rooms in suites. There are also several double rooms. All ceilings are nine feet high. Each bedroom has a clothes closet and basin with hot and cold running water. The rooms are provided with heavy oak furniture of the Mission type. There are four shower baths on each floor. All the water used in the Halls is filtered.

The entrance for students to each Hall is from the campus, and leads directly into a large assembly room 60 feet square. This room runs up through two stories and has a large open fireplace opposite the entrance. It is furnished in heavy leather-covered oak. At one side of the main entrance is the office of the Hall, and on the other a reception room. In the basement is space for trunk storage. All baggage should be addressed to Hartley, Livingston, or Furnald Hall, Columbia University, and all charges should be prepaid.

University Commons

The University Commons, in University Hall, is operated under University management for the benefit of officers and students. The service is *à la carte*, or regular board may be secured for $6 a week.

Other Accommodations

Besides the dormitories and the Greek Letter Society club-houses there are many good boarding-houses and apartments near the University, a card-catalogue of which is kept at Earl Hall.

Institute of Arts and Sciences

In addition to the regular courses of instruction, numerous public lectures are given by the Institute of Arts and Sciences, ordinarily by persons of distinction who are not members of the teaching staff. The University maintains close relations with the other educational and public institutions of the city, and students enjoy unusual privileges at them. Students are also frequently given the opportunity to enjoy important dramatic and musical performances at a considerable reduced cost.

St. Paul's Chapel

St. Paul's Chapel, the gift of Olivia Egleston Phelps Stokes and Caroline Phelps Stokes, as a memorial to their parents, is in the form of a cross, the greatest length being 122 feet and the width at the transepts 77 feet. In all 1,050 sittings are provided. Of these, 120 are in the choir, which, as in the English cathedrals, may itself be used for a religious service at which the attendance is small.

Service, at which attendance is voluntary, is held every week-day except Saturday, at noon—the period from 12 to 12.20 being set apart by the University for religious exercises—and on Sunday afternoons at 4 P.M. There are also frequent organ recitals.

Special University services are held on the Wednesday preceding the Thanksgiving recess and on the first Wednesday of the second half year.

The chaplain and Mrs. Knox are at home to students (413 West 117th Street) each Sunday afternoon after the service.

Earl Hall

Earl Hall, the home of the religious, philanthropic, and social organizations and interests, is open to all students, without expense, from 8.30 A.M. to 10 P.M. daily, under the management of its Secretary, who is also Secretary of the University Young Men's Christian Association. Provision for the meetings of student organizations is made in the following order: Societies the purpose of which is (1) primarily religious; (2) primarily philanthropic; (3) primarily literary; and (4) miscellaneous student organizations. The building is also much used as a general student club house.

Student Organizations

The various student organizations, while self-governing, are subject to the following regulations: The schedules of public contests and performances must be approved by the University Committee on Student Organizations; budgets for expenditure are approved and checked by the Comptroller of Student Organizations; the University Committee on Athletics, consisting of three graduates, two students and two University officers, adopt and administer rules of eligibility not involving questions of scholarship and govern participation in inter-collegiate athletics. A pamphlet containing the full regulations, the constitution of the Athletic Association and the constitution of the Board of Student Representatives may be obtained from the Secretary of the University.

The Degree of A.M.

A college graduate who completes with marked distinction one of the regular professional courses may be recommended for the degree of Master of Arts if, while pursuing his professional course, he shall have taken additional work, under the Faculty of Pure Science, Philosophy or Political Science, to the extent of a major subject, and have presented a satisfactory essay upon an assigned topic. A detailed statement of the requirements for this degree and also for the Ph.D., with a list of subjects which may be offered, will be found in the *Announcement of the Faculties of Political Science, Philosophy and Pure Science.*

Fellowships

For information as to the twelve University Fellowships, of the annual value of $650 each, and the several endowed fellowships open to qualified candidates for the degrees of Master of Arts and Doctor of Philosophy, see the *Announce-*

ment of the Faculties of Political Science, Philosophy and Pure Science, or the University Catalogue.

The following are of particular interest to students of Mines, Engineering and Chemistry, who are advised to familiarize themselves with the special regulations governing them:

The Tyndall Fellowship for the Encouragement of Research in Physics, endowed by Professor John Tyndall, and of an annual value of $648; the Barnard Fellowship for Encouraging Scientific Research, endowed by the bequest of the late President Barnard, annual value $412.50; the Ernest Kempton Adams Research Fellowship, founded by Mr. Edward Dean Adams in memory of his son, Ernest Kempton Adams, annual value $1,250; the Samuel Anthony Goldschmidt Fellowship in Chemistry, of an annual value of $670.30, and the William Petit Trowbridge Fellowship in Engineering, of an annual value of $500.00.

Students

In 1913-14 the registration in the Schools of Mines, Engineering and Chemistry is as follows:

First-year class	212
Second-year class	154
Third-year class	141
Fourth-year class	133
Non-matriculated	42
Students from Columbia College	12
Total	694

Of students registered, 50 already held a college or technical degree, representing 30 institutions. In addition there are registered under the Faculty of Pure Science as candidates for the A.M. and Ph.D. degrees 26 students with some branch of Engineering (including 22 in Highway Engineering) and 68 with Chemistry as a major subject.

ALUMNI ORGANIZATIONS

The Alumni Association of the Schools of Science of Columbia University includes in its membership graduates of the Schools of Mines, Engineering and Chemistry. Associate membership is open to non-graduates, members of classes that have graduated.

Honorary membership is open to all persons eminent in Science who are or have been connected with any of the Schools of Science of Columbia University.

Its officers for 1912-13 are:

President, Benjamin B. Lawrence, E.M., '78.
Vice-President, Robert Van A. Norris, E.M., '85.
Treasurer, John S. Douglas, E.E., '90.
Secretary, Ralph E. Mayer, C.E., '79.
Post Office Substation 84, New York City.

Board of Managers

W. M. Meserole, C.E., '81.
F. D. Dodge, Ph.B. (Chem.), '88.
D. M. Myers, M.E., '01.
G. E. Hutchinson, E.E., '09.
G. C. Stone, Ph.B., '79.
I. H. Woolson, E.M., '85
H. A. Prosser, E.M., '96
R. E. Dougherty, C.E., '01

Delegates to the Board of Directors of the Alumni Federation

Charles B. Going, Ph.B., '82
Edgar G. Barratt, C.E., '84.
Daniel E. Moran, C.E., '84.

A complete list of the Alumni, giving the addresses of each, and in the case of those who are members of the Association, a detailed record of their professional careers, is published and may be had on application to Professor R. E. Mayer, Secretary, Columbia University.

The Alumni Secretary will also be glad to put prospective students in communication with Alumni in different parts of the country. Such Alumni are often able to furnish information in a personal interview regarding the Schools of Mines, Engineering and Chemistry which inquirers at a distance could obtain in no other way.

Class Group Societies

Society of the Early Eighties:
Francis E. Ward, '81 S, President
Girard Romaine, '82, Secretary, 68 Broad Street.

Society of the Older Graduates:

Pierre de P. Ricketts, '71 S, '76 Ph.D., President.
William de L. Benedict, '74 S, Secretary, 19 Cedar Street.

Society of the Upper Eighties:

Charles Halstead Mapes, '85, 89 S.
Edward L. Dodge, '88 S, Secretary, 44 Court Street, Brooklyn, N. Y.

THE ALUMNI FEDERATION OF COLUMBIA UNIVERSITY

Organized 1913

(To be Incorporated)

Officers

President

JOHN HOWARD VAN AMRINGE, '60

Vice-President

WILLIAM CURTIS DEMOREST, '81, '83 L

Treasurer

GUSTAVUS TOWN KIRBY, '95 S, '98 L

Executive Secretary

GEORGE BROKAW COMPTON, '09, '13 L

Recording Secretary

LEVERING TYSON, '11 A.M.

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THOMAS B. STEARNS, '81 S—Colorado
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Charles Buxton Going, '82 S
Edgar G. Barratt, '84 S
Daniel E. Moran, '84 S

From the Doctors of Philosophy

Edmund S. Joy, '88 L, '92 Ph.D.
Floyd Appleton, '93, '06 Ph.D.
Charles A. Downer, '01 Ph.D.

SCHOOL ASSOCIATIONS

(Affiliated with the Federation)

Association of the Alumni of Columbia College:
Ambrose D. Henry, '84, President, 71 Broadway.
George Brokaw Compton, '09, '13 L, Secretary, Columbia University.

Association of the Alumni of the College of Physicians and Surgeons of Columbia University:
Walter Mendelson, '79 M, President, 159 West 74th Street.
Henry E. Hale, '96 M, Secretary, 770 West End Avenue.

Alumni Association of the Law School of Columbia University:
George L. Ingraham, '69 L, President, 80 Irving Place.
Lawrason Riggs, Jr., '03, '06 L, Secretary, 27 William Street.

Alumni Association of the Schools of Science of Columbia University:
(Officers given above.)

Association of Doctors of Philosophy of Columbia University:
Rudolf Tombo, Jr., '01 Ph.D., President, Columbia University.
Adam Leroy Jones, '98 Ph.D., Secretary, Columbia University.

Columbia Alumni Clubs

(Affiliated with the Federation)

Buffalo: W. J. Donovan, '05, '08 L, President, 604 Iroquois Building, Buffalo, N. Y. A. H. Hopkins, '08 F.A., Secretary, German Insurance Company Building, Buffalo, N. Y.

Colorado: Cyrus L. Pershing, '08 M, President, Stedman Building, Denver, Colo. John E. Fetzer, '08 L, Secretary, 824 Equitable Building, Denver, Colo.

Cuba: Jose Primelles, '87 S, President, 37 I Street, Vedado, Havana, Cuba. Humberto Fonts, '09 S, Secretary, Empedrado 59, Havana, Cuba.

District of Columbia: Marcus Benjamin, '78 S, President, 1703 Q Street, N. W., Washington, D. C. George Oakley Totten, Jr., '91 F.A., Secretary, 808 Seventeenth Street, N. W., Washington, D. C.

Illinois: William M. L. Fiske, '00, President, 234 South La Salle Street, Chicago, Illinois. Emory Hill, '04, Secretary, 122 South Michigan Boulevard, Chicago, Ill.

Los Angeles: James H. Seymour, '83 M, President, 310 Grant Bldg., Los Angeles, Cal. Paul J. Pitner, '05 S, Secretary, Whittier Extension Co., Union Oil Bldg., Los Angeles, Cal.

Maryland: N. Winslow Williams, '83 L, President, Fidelity Building, Baltimore, Md. George C. Saunders, '98 S, Secretary, 3012 Harford Road, Baltimore, Md.

Mexico: Victor M. Braschi, '81 S, President, Apartado 830, Mexico City, Mexico. George W. Knoblauch, '03 S, Secretary, P. O. Box No. 830, Cadena No. 2, Mexico City, Mexico.

Minnesota: Charles N. Dohs, President, '94 L, 876 Osceola Avenue, St. Paul, Minn. R. T. La Vake, '09 M, Secretary, Pillsbury Building, Minneapolis, Minn.

Nebraska: Harley G. Moorhead, '02 L, President, 114 South 38th Street, Omaha, Neb. N. R. Brigham, '13 F.A., Secretary.

New Jersey: Ralph E. Lum, '00, President, 765 Broad Street, Newark, N. J. William O. Wiley, '82, Secretary, 44 South Clinton Street, East Orange, N. J.

Northern New York: Roelif H. Brooks, '00, President, 80 Lancaster Street, Albany, N. Y. Barnard Bronson, '08, Secretary, Albany Normal College, Albany, N. Y.

Oregon: Louis P. Hewitt, '07 L, Secretary, 615 Oregonian Building, Portland, Oregon.

Philadelphia: Henry Kraemer, '95 S, President, 145 North Tenth Street, Philadelphia, Pa. H. F. Sanville, '92 S, Secretary, Hale Building, Philadelphia, Pa.

Pittsburgh: George S. Rice, '87 S, President, U. S. Bureau of Mines, Pittsburgh, Pa. J. H. Marsching, '02 A.M., Secretary, 1826 Frick Building, Pittsburgh, Pa.

San Francisco: J. R. Clark, '95 M, President, Ortmann Building San Francisco, Cal. John C. Spencer, '82, '85 M, Secretary, Butler Building.

Utah: Alvah C. Lewis, '77 M, President, 352 East First Street, Salt Lake City, Utah. C. H. Doolittle, '85 S, Secretary, 1242 East South Temple, Salt Lake City, Utah.

Washington: H. K. Benson, '07 Ph.D., President, University of Washington, Seattle, Wash. Henry M. Ramey, Jr., '01 L, Secretary, Central Building, Seattle, Wash.

Yonkers: William Forster, '81, President, 59 Wall Street, New York. James F. Prince, '08, Secretary, 149 N. Broadway, Yonkers, N. Y.

LOCAL ASSOCIATIONS

(Not Affiliated with the Federation)

Indiana: M. Thorner, '98 M, President, 234 Indiana Pythion Building, Indianapolis, Ind. Mark H. Miller, '97 L, Secretary, Lemcke Building, Indianapolis, Ind.

Kansas City: John C. Meredith, '86 L, President, Commerce Building, Kansas City, Mo. Walter S. Sutton, '07 M, Secretary, 810-815 Rialto Building, Kansas City, Mo.

St. Louis: Julius S. Walsh, '64 L, President, 3628 Delmar Avenue, St. Louis, Mo. William E. Baird, '02 L, Secretary, Law Department, City Hall, St. Louis, Mo.

Wisconsin: Alfred W. Gray, '99 M, President, Goldsmith Building, Milwaukee, Wis. H. W. Buemming, '95, F.A., Secretary, 521 Jackson Street, Milwaukee, Wis.

ACADEMIC CALENDAR
1914-1915

1914

July 6—Monday. Fifteenth Summer Session opens.
Aug. 15—Friday. Fifteenth Summer Session closes.

Sept. 14—Monday. Entrance examinations and examinations for deficient and debarred students begin.
Sept. 16—Wednesday. Registration begins.
Sept. 22—Tuesday. Registration ceases for students previously matriculated. Later applications received only on payment of an additional fee of $5.
Sept. 23—Wednesday. First half-year, 161st year, begins. Registration ceases for students not previously matriculated. Later applications received only on payment of an additional fee of $5. Fellows and Scholars to report to the Registrar.
Sept. 24—Thursday. Lectures and recitations begin in courses.
Oct. 20—Tuesday. Stated meeting of University Council.
Nov. 3—Tuesday. Election Day, holiday.
Nov. 25—Wednesday. University Service, St. Paul's Chapel.
Nov. 26—Thursday, to November 28, Saturday, inclusive, Thanksgiving holidays.
Dec. 6—Sunday. Commemoration Service in St. Paul's Chapel.
Dec. 15—Tuesday. Stated meeting of University Council.
Dec. 21—Monday, to

1915

Jan. 2—Saturday, inclusive, Christmas holidays.
Jan. 4—Monday. Last day for filing applications for entrance examinations.
Jan. 14—Thursday. Mid-year entrance examinations begin.
Jan. 20—Wednesday. Mid-year examinations begin.
Feb. 2—Tuesday. First half-year ends.
Feb. 3—Wednesday. Second half-year begins. University service in St. Paul's Chapel. Registration ceases for students entering second half-year. Later applications received only on payment of an additional fee of $5. Fellows and Scholars to report to Registrar.
Feb. 12—Friday. Alumni Day.
Feb. 16—Tuesday. Stated meeting of University Council.
Feb. 22—Monday. Washington's Birthday, holiday.
April 1—Thursday, to April 5, Monday, inclusive, Easter holidays.

April 20—Tuesday. Stated meeting of University Council.
May 1—Saturday. Last day for filing applications for scholarships.
May 3—Monday. Deficiency examinations begin for fourth-year students only.
May 8—Saturday. Last day of instruction for fourth-year students.
May 12—Wednesday. Final examinations begin in subjects of the fourth year only.
May 15—Saturday. Last day of instruction for second- and third-year students.
May 17—Monday. Final examinations begin.
May 30—Sunday. Baccalaureate service.
May 31—Monday. Monday. Class Day. Memorial Day, holiday.
June 2—Wednesday. Commencement Day.
June 9—Wednesday. Second half-year ends.
June 14—Monday. Entrance examinations begin.
July 6—Tuesday. Sixteenth Summer Session opens.
Aug. 13—Friday. Sixteenth Summer Session closes.
Sept. 20—Monday. Entrance examinations and examinations for deficient and debarred students begin.
Sept. 22—Wednesday. Registration begins.
Sept. 28—Tuesday. Registration ceases for students previously matriculated. Later applications received only on payment of an additional fee of $5.
Sept. 29—Wednesday. First half-year, 162d year, begins. Registration ceases for students not previously matriculated. Later applications received only on payment of an additional fee of $5. Fellows and Scholars to report to the Registrar.
Oct. 19—Tuesday. Stated meeting of University Council.
Nov. 2—Tuesday. Election Day, holiday.
Nov. 24—Wednesday. University service in St. Paul's Chapel.
Nov. 25—Thursday, to November 27, Saturday, inclusive, Thanksgiving holidays.
Dec. 12—Sunday. Commemoration service in St. Paul's Chapel.
Dec. 21—Tuesday. Stated meeting of University Council.
Dec. 22—Wednesday, to Saturday, January 1, 1914, inclusive, Christmas Holidays.

UNIVERSITY OF ILLINOIS-URBANA
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